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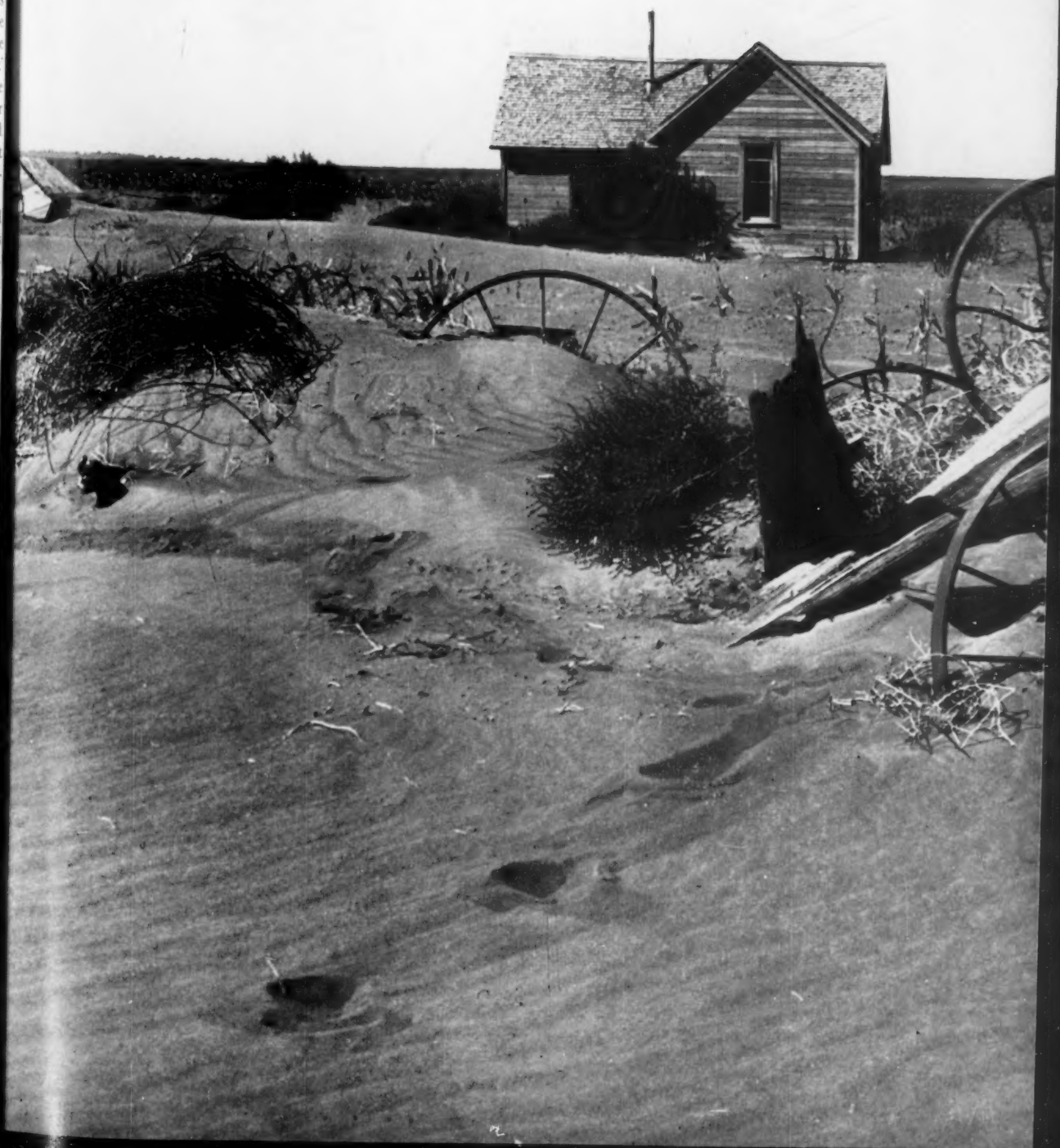

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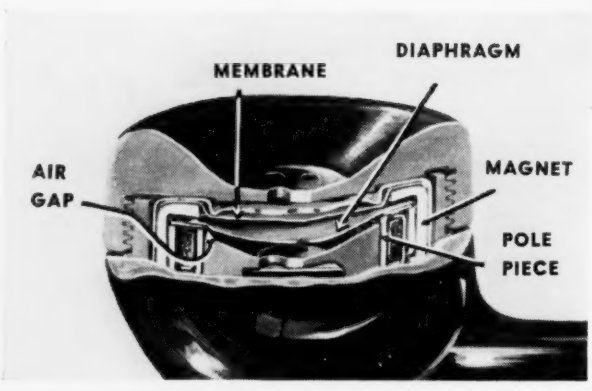

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THE SCIENTIFIC MONTHLY

VOL. LXXIII AUGUST 1951 No. 2

Contents

Abandoned Farmstead Showing Disastrous Effect of Wind Erosion . . . . . Cover
(U. S. Soil Conservation Service Photo)

The National Research Fellowships . . . . . *Myron J. Rand* 71

Heat and Mass Flow Analyzer . . . . . *V. Paschkis* 81

Bright Future . . . . . *Emily Ericsson* 89

D. H. Lawrence and Science . . . . . *Charles I. Glicksberg* 99

Native Astronomy in Micronesia . . . . . *Ward H. Goodenough* 105

Science and Values . . . . . *Erwin W. Fellows* 111

Ernest Solvay . . . . . *Charles S. Glenn* 114

Three Poems: City in the Tall Night, Heat, Lecture on Psychology . . . *Daniel Smythe* 121

Science on the March:

New Archaeological Site in Panama . . . . . *Kenneth W. Vinton* 122

Weeds, Insects, Plant Diseases, and Dust Storms . . *Robert L. Piemeisel, Francis R. Lawson,* and *Eubanks Carsner* 124

Nutrition Under the Chinese Communist Government . . . . . *Wm. H. Adolph* 128

A Pineapple Landscape in Mindanao . . . . . *Alden Cutshall* 130

Book Reviews by *R. Tucker Abbott, Percy Black, Stanley A. Cain, Wendell H. Camp, Saul Dushman, F. R. Fosberg, John Halberg, B. Clifford Hendricks* and *E. Roger Washburn, Frank Proschan, Harris Proschansky, Malcolm H. Soule,* and *Charles E. Whitmore* 134

Annual Meeting, AAAS, Philadelphia, Pennsylvania, December 26–30, 1951

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Science and Technology

(From the Month's News Releases)

Slow Plane Through Arkansas

The first airplane designed for a single special job is Ag-1 (for agriculture). Constructed at Texas A & M, under contract with the CAA, the plane can carry 12,000 pounds of insecticide spray or dust and can fly low and slow (45 mph), take off or land on short, unimproved runways. It is expected to cut the accident rate in crop-control flying.

Film Dosimeters

A compact film badge developed by the National Bureau of Standards for industrial safety programs and for monitoring gamma and X-radiation in civilian defense, has a range from 120 kev to about 10 mev. Accuracy limits within the ranges from 1 to 50 r and from 500 to 10,000 are ± 12%; in the center range—from 50 to 500 r—the resulting limits are ± 20%.

The School of Aviation Medicine has recommended the use of self-developing film made into a badge that may be pinned on a shirt or attached to a dog tag. One of five narrow strips of film in a pack measures radiation up to 75 r; another records up to 420 r; and the remaining three are for control and checking purposes. Several packs may be worn successively over a period of time, the sum of their exposures showing the amount of total radiation endured.

On the Subject of Corn

The Department of Agriculture has embarked on a program of collecting, classifying, perpetuating, and distributing to plant breeders the more than 2,000 types of corn native to the Western Hemisphere. Funds will be provided by the Technical Cooperation Administration as a part of the Point IV program. Maintenance and distribution of the collections, as well as perpetuation through periodic replanting to replace old seed, will be financed and handled through the facilities of the National Research Council. Preservation of germ plasm and improvement and increased production of corn are the major objectives.

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Practical Loom

The Southern Regional Research Laboratory of the USDA has developed an improved, inexpensive loom attachment for weaving extra-tight, naturally waterproof cotton fabrics, also hard-to-weave fabrics. It is easily installed on standard textile looms, is simple to adjust and use, and improves the general operation of the loom by easing the strain on the warp yarns.

Publications Noted

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Cuddly new cats and teddy bears have been especially treated inside to prevent formation of allergenic dust in the stuffing, and the fur may be kept free of house dust with a vacuum cleaner.

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More than 16,000 families have summer homes in the National Forests, one of the approved "multiple uses" for this public land. Summer home sites are opened, in attractive and accessible spots, as the demand warrants, and may include 5 to 30 building lots of about half an acre each. Local forest officers issue permits, which cost $10 to $50 per year.

Modern Design

Moduplan employs modular construction, as its name implies. Its main economies are in labor costs, as the all-steel construction is no cheaper than other kinds of good construction. Its unique feature is the frame, which is of flagpole-like units set 8 feet apart in 2 feet of cement. The house is claimed to be earthquake-, fire-, rat-, rot-, and termite-proof. Flexibility is another feature of Moduplan homes.

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A new wind velocity recorder provides both instantaneous indication and a strip chart record of velocities of between 0 and 200 per hour. A dual-range instrument is furnished for use with either a directional or a horizontally nondirectional probe of the thermopile type, temperature-compensated to eliminate effects of temperature and rate of change of temperature. A thermostatically controlled heater to prevent icing can also be supplied. The manufacturer thinks it is particularly suitable for air pollution research, public gas industries, microclimate research, industrial process control, and testing of heat and ventilation systems.

Tour de Force

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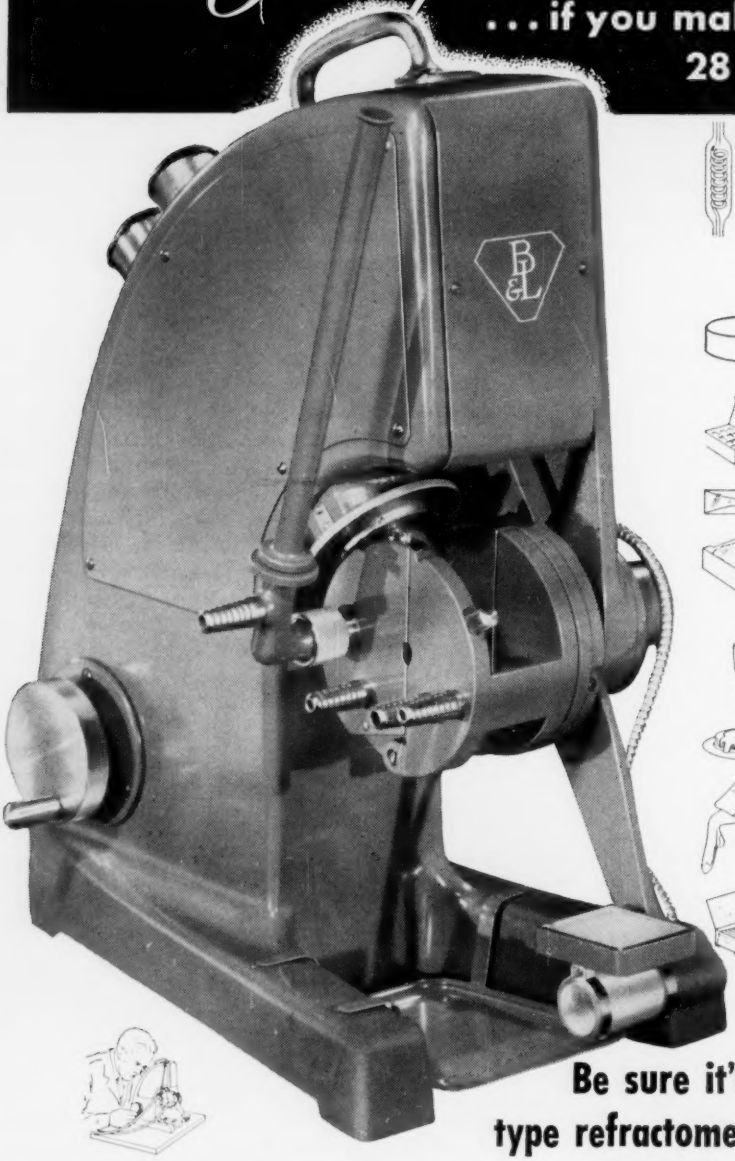

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THE
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AUGUST 1951

The National Research Fellowships

MYRON J. RAND

The author is scientific associate at the National Research Council, the agency that administers the postdoctoral fellowship program whose results are described. He attended the University of New Hampshire and Columbia University, receiving the Ph.D. degree in physical chemistry from the latter institution in 1950.

THE National Research Fellowships, a program of postdoctoral scientific research fellowships supported by the Rockefeller Foundation, have been administered by the National Research Council for thirty years. This program provides awards in all the natural and the basic medical sciences; a Fellow may study, and gain competence in research, with a scientist of his own choosing at any suitable institution. The conduct of the program is entirely in the hands of scientists, and the fellowships are financed by private, philanthropic funds.

Under these seemingly ideal conditions, more than thirteen hundred young scientists have received one or more years of advanced training and experience in research. It should now be possible, by study of this bellwether of fellowship plans, to provide at least general answers to such questions as: What can a program of fellowships for advanced training do? How efficient is it as a method for producing scholars and expert research workers in a field of science? Although no study can measure with any exactness the effect of the program, it is worth while to determine, if possible, whether the fellowships have contributed to the spectacular rise from mediocrity to world leadership in scientific research which the United States has accomplished during the one generation in which the fellowship experiment has been in progress.

Certainly the men who originated the National Research Fellowships aimed at just such a stimulation of research. In the minutes of the joint meeting of March 11, 1919, of the Council of the National Academy of Sciences with the Executive Board of the National Research Council, this paragraph appears:

> Dr. [A. A.] Noyes *moved*: That the Executive Board approve the undertaking by the Council of a project of which the broad purpose is to promote fundamental research in physics and chemistry in educational institutions —the project to consist primarily in the organization and maintenance of a system of National Research Fellowships to be awarded to persons who have already demonstrated a high order of ability in research, for the purpose of enabling them to carry on investigations at educational institutions making adequate provision for the prosecution of research in physics and chemistry. *Adopted*

This was no pious statement of good intentions. It placed on record the culmination of more than a year of thinking and negotiation. The National Research Council and the Rockefeller Foundation were both seriously concerned with raising scientific research in this country from its low estate; there had been formal discussions around the conference table, informal talks over luncheons, and lengthy

correspondence. Eventually a plan had been agreed upon which looked both practical and capable of immediate initiation. The foundation appropriated the funds, and the scientists of the council began work on their project: for the good of the country, the best scientific talent would be encouraged to apply for fellowships for further study beyond the doctor's degree—further study, and particularly training and experience in the science and art of research.

The fellowship fields were soon broadened to include the medical, biological, and earth sciences. During the twenties, the program became firmly established, and the number of Fellows rose steadily. A great business depression and, later, another great war had their inevitable effects. In 1950, with thirty years of the experiment past, former National Research Fellows were to be found in every corner of the structure of American science. There is now scarcely a major university without one, and some have twenty or more. They are in industry, in government-sponsored research, and on the staffs of hospitals, museums, and observatories. There are half a dozen university presidents, a liberal sprinkling of deans of science, and scores of department heads; there are research directors of industry, and research scientists of the laboratories of the Navy, the Atomic Energy Commission, and the Department of Agriculture. Well over 95 per cent of the surviving Fellows are still active in research work.

Since the end of the first world war, the United States has risen from a distinctly second-rate scientific power to a position of world leadership in physics, chemistry, biology, and medicine. This leadership is in part a result of the tragic toll of two great wars on the manpower and economy of Europe; but there is no doubt that during this period scientific research in the United States made enormous progress. How much of this improvement is due to the National Research Fellowships program? The question has often been debated by the scientists who choose the Fellows, always aware of their responsibilities to the aims of the founders. The late Isaiah Bowman wrote in 1934:

> It has long perplexed us [in the National Research Council] to find an answer to the question: How do you know that the fellowship plan is responsible for the marked advance of science in this country? Naturally, if a good job of selection is done, the resulting Fellows will be in general the best, whether or not they receive exceptional training. At our meeting . . . this question was put, and the answer given: before 1920 the level of scholarship was being raised, no doubt, but at an average or normal rate, as in the past; coincident with the Fellowship plan, there was a rapid rise in the rate and an end result that met all expectations and put the United States in a far higher class than it had occupied. . . .

During the first thirty years of the National Research Fellowships 1,359 scientists—including the Nobel prize winners Compton, Lawrence, and Stanley, and sixty-two other members of our National Academy of Sciences—received an average of one and one half years of special training at an institution of their choice. For this training the Rockefeller Foundation paid about $4,800,000. As an investment in the national welfare, this sum may be compared with the cost of—for example—military aircraft. It will buy one B-36.

It is neither accurate nor desirable to attribute this stupendous bargain in the national development and defense to the happy inspiration of any one scientist. By the end of World War I it was evident to many men of vision that an enormous expansion of American science was necessary. Submarine warfare, poisonous gases, tanks and other mobile weapons, and the obvious possibilities of aircraft—these and many other developments showed plainly that modern war was a highly technical, a highly scientific, business, and in the interests of its own defense no country could long afford to lag in its scientific development. Our own scientific successes had been moderate, at best, and many of the scientific leaders of the war were either foreign-born or foreign-trained. In addition, it was realized that we had been dependent upon the German chemical industry to an unhealthy extent and that keen industrial competition among nations was certain to follow the war.

In this atmosphere, and at a time of intense nationalism, the Rockefeller Foundation and the National Research Council began their discussions of possible remedies early in 1918. The foundation, established five years before, was planning its peacetime program. The council, which had been organized within the National Academy of Sciences, was less than two years old; but there were giants guiding it. Its chairman was George Ellery Hale, a lifelong and universally honored worker in international scientific effort, to whom the Palomar telescope now stands as a monument; the vice chairman and executive officer was the energetic Robert A. Millikan, who was to win the Nobel prize in 1923 for his determination of the charge on the electron, and his photoelectricity researches in support of the Einstein concept of the corpuscular nature of light rays.

One of the proposals the Rockefeller Foundation was considering was for an institute for research in physics and chemistry, similar to the Rockefeller Institute for Medical Research. This was suggested by Simon Flexner, a member of the foundation and

the director of the medical institute. On February 5, 1918, George Vincent, president of the foundation, wrote to Dr. Millikan asking for his comments on the proposal.

As soon as Millikan had read the letter, he recognized its importance. He showed it to Hale, and suggested that the reply be delayed until a representative group of physicists and chemists could be gathered to discuss the plan. Millikan himself had definite ideas; and he was to reveal them before he had planned to. Shortly afterward, he received a visit from Flexner, who told him that there was an excellent chance that the Rockefeller board would look favorably upon the establishment of the institute for physics and chemistry, and—in short—could he present to the board the name of Robert A. Millikan as a possible director of the institute?

Dr. Millikan argued himself out of this most important job. He was strongly opposed to centralization of any kind. He believed that the ultimate return from philanthropic funds would be greater if a dozen or so "research institutes" could be set up in universities, so that the money would be spent for actual research and training, using existing facilities and improving them in the process. This was the opinion Millikan presented when the group of research scientists met to consider the foundation's proposal. It is not recorded whether the discussion was spirited, but the final vote was 9 to 7 for decentralization.

There was considerable concern during the meeting over the negotiation and attendant delays necessary in choosing and gaining the cooperation of the participating institutions. On one suggestion, however, the sixteen men could quickly reach agreement, and it was unanimously recommended that a program of postdoctoral research fellowships for young Ph.D.s was desirable and might well accomplish the same thing as the "institute" scheme. It would, in effect, make any large university a participating institution, and the presence of the Fellow in the university would have as salutary an effect upon the research atmosphere of the school as the faculty and facilities of the school would have upon the Fellow. In addition, it was suggested that the stipend be set higher than that of the usual fellowship, to induce the best men to seize this opportunity for additional training without distraction—and to counteract, in some measure, the lure of industrial salaries.

When a report of the discussions was made to Dr. Vincent, he agreed to recommend to his board favorable action on that part of the project on which the scientists seemed to be in agreement. For several months there was much discussion among the members of the Rockefeller Foundation on both the fellowships and the smaller institutes. Dr. Millikan consistently urged separation of the two ideas. Finally in March 1919, the academy and council submitted to the foundation a formal proposal for a "project for promoting fundamental research in physics and chemistry in educational institutions in the United States," establishing fellowships to be supported by the foundation and awarded by the council. At its meeting on April 4, 1919, the board of the foundation appropriated $50,000 for the first year of operation, and pledged $500,000 for the first five years.

The council lost no time. The Fellowship Board had already been chosen. Dr. Flexner was chairman; other members were Hale, Millikan, A. A. Noyes, Wilder D. Bancroft, Henry A. Bumstead, E. P. Kohler, and Charles E. Mendenhall. The board met twelve days after news of the grant was received. Already posters were appearing on bulletin boards in universities, and newspapers had printed the story. Before a month had passed the first Fellows had been chosen, and by the end of the year the board had appointed thirteen Fellows from among fifty-four applicants.

The young scientists selected more than justified the honor. All attained high positions. Eleven became full professors or chairmen of departments in universities; one chose government, one industry. Four—Edwin J. Cohn, Arthur H. Compton, Morris Kharasch, and W. H. Rodebush—were elected to the National Academy of Sciences, and six years after finishing his fellowship Compton shared with C. T. R. Wilson the Nobel prize in physics.

The establishment of the physics and chemistry fellowships in the spring of 1919 brought an immediate stirring in other scientific fields. Before ten days had passed, the Advisory Board of the Wistar Institute had resolved: "In our opinion, it is of extraordinary importance that the National Research Council establish in biological sciences fellowships similar to those established in physics and chemistry. . . ." This resolution was read to the April 26 organizational meeting of the council's Division of Biology and Agriculture, which had already appointed a committee to consider whether fellowships were needed in biology. The group gathered opinions from about thirty universities and reported them; the division duly put on record a motion that it was indeed desirable to ask for support for such fellowships. Those appointed to do the planning found progress slow and uncertain, however; the status and the needs of the biological sciences were different from those of physics and chemistry—for example, there was little competi-

tion for young biologists from industry. It was not until January 1923 that the document entitled "The Desirability of Post-Doctorate Fellowships in the Biological Sciences" went to the Rockefeller Foundation. In March the foundation appropriated $20,000 for fellowships for 1923, and pledged $325,000 for a five-year period. The Fellowship Board held its first meeting a few days later, and nine Fellows were appointed during 1923.

Meanwhile, the establishment of the physics and chemistry fellowships had suggested to the council's Division of Medical Sciences a remedy for the scarcity of young research workers and teachers in the preclinical departments of medical schools. This shortage was disturbing to those doctors who realized that advances in diagnosis, treatment, and prevention of diseases were founded upon fundamental research in such fields as anatomy, biochemistry, bacteriology, pathology, pharmacology, and physiology. By the end of 1919 the division had appointed a group to investigate the extent of the shortage, and the committee's report, published in the *Journal of the American Medical Association,* brought wide attention to the problem. The Rockefeller Foundation and its General Education Board soon called a conference to discuss the supply of medical teachers and investigators, and the conference recommended that the foundation approach the National Research Council with the aim of establishing research fellowships for men and women who had the desire and ability for a career in academic medicine. The council was understandably receptive to the idea. Early in 1922 the foundation and the General Education Board agreed to appropriate $100,000 a year for a five-year period, with $50,000 being made available for 1922. The Medical Fellowship Board held its first meeting on April 18, 1922, and before the end of the year had appointed thirty-one Fellows.

Three fellowship programs in the physical sciences, biological sciences, and medical sciences were thus in full operation by the end of 1923. These fellowships—the first general, nation-wide postdoctoral awards in scientific research—were apparently quite intriguing, for over the years 1923–31, about 18 per cent of all the young Ph.D.s in the natural sciences applied for them, and about 5 per cent were successful. The corresponding figures for the medical sciences, which were graduating four or five times as many men, were 1.7 per cent and 0.4 per cent. The history of "supply and demand" of the fellowships is shown in Figure 1. Tables 1 and 2 contain additional data.

The early depression years saw the peak of the program. In 1933, four hundred—30 per cent—of the new Ph.D.s applied for fellowships; the rise among M.D.s was not as marked. By 1934, the improvement in the health of American research in the natural sciences was quite evident, and it was decided to restrict the fellowship funds to about a third of the original amount; research in the medical sciences was still inadequate, however, and this program was not reduced. In 1937 the two programs in the physical and biological sciences were combined under the Natural Sciences Fellowship Board, aided by screening committees of National Research Council divisions. During the late thirties the demand continued, with about 10 per cent of the new Ph.D.s applying for fellowships that were available for less than 2 per cent.

In the years of World War II, there were jobs for young scientists to do which were considerably more urgent than academic research, and there was little demand for fellowships. Furthermore, the training of scientists lagged, and it was not until the application season at the start of 1950 that the program appeared "normal" once more.

Perhaps three sets of figures from the spring of 1950 will represent at once both the present state of the National Research Fellowship program and the best beginning that can be made to the study of the "results" of the program. The significance of these figures should be considered with the aims expressed in 1918 in mind:

Eleven per cent of the applications for 1950-51 could be granted. This is the lowest figure in the history of the program.

Of the nineteen new Fellows who are studying in the United States, seven have chosen to work under men who were themselves once National Research Fellows.

Of the thirty new members elected to the National Academy of Sciences, nine were once National Research Fellows.

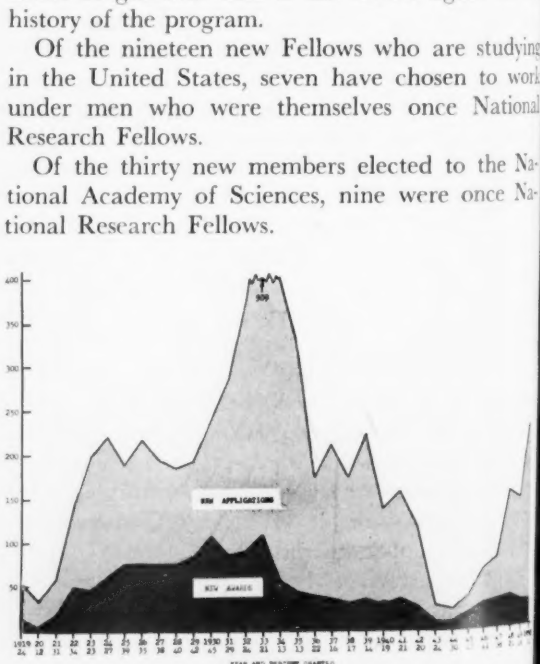

FIGURE 1.

TABLE 1

SUPPLY AND DEMAND

YEAR	NATURAL SCIENCES		MEDICAL SCIENCES	
	New Applications Received	New Appointments	New Applications Received	New Appointments
1919–20	54	13		
1920–21	32	4		
1921–22	59	18		
1922–23	51	17	91	31
1923–24	116	29	82	16
1924–25	141	37	80	23
1925–26	114	56	74	18
1926–27	141	57	76	18
1927–28	114	57	80	17
1928–29	145	61	39	13
1929–30	149	67	42	14
1930–31	182	88	57	19
1931–32	198	66	86	17
1932–33	275	76	96	12
1933–34	399	82	110	25
1934–35	302	44	99	9
1935–36	253	35	62	6
1936–37	131	30	41	7
1937–38	157	24	53	10
1938–39	124	22	48	7
1939–40	154	23	67	9
1940–41	78	18	59	8
1941–42	91	21	65	11
1942–43	71	17	42	6
1943–44	19	6	6	0
1944–45	16	4	4	2
1945–46	26	13	8	3
1946–47	35	19	29	7
1947–48	32	12	45	17
1948–49	78	14	74	18
1949–50	66	14	77	12
1950–51	149	17	78	7

Yet in no year were fellowships granted to as many as one out of twenty of those who received doctors' degrees.

Further study of the effectiveness of the fellowship program must inevitably examine the accomplishments of the Fellows themselves, and their positions as scientific and educational leaders. Since they were all already trained to the doctorate level before beginning the fellowship years—as are all applicants for the awards—it is important to consider the process of choosing a National Research Fellow, and what occurs during the fellowship tenure.

The fellowship board that decides which applicants shall receive the awards is, quite literally, making an investment. It is risking several thousand dollars of private capital in a long-term investment which, even if successful, returns the principal sum only in intangible ways. The problem of the board is formidable: it must be able to detect in young scientists those qualities which will make them the research leaders and teachers of twenty years later, and to be reasonably sure that the award of the fellowship will accelerate their development. A Fellow whose extra training results only in his ability to command a more lucrative position is a failure for purposes of the fellowship program. The aim of the Fellowship Board today is what it was thirty years ago.

Every precaution is taken to make the choice wisely. The members of the Fellowship Board are scientists well known and respected not only for their accomplishments in their researches but also for the breadth of their wisdom. Well in advance of their meeting, they have copies of the applications, the letters of recommendation, the university transcripts, and the fairly complete statements which the applicant is required to make concerning the goals of his professional training and the plan

TABLE 2

DOCTORATES GRANTED IN THE UNITED STATES

Year	Doctorates in the Sciences*	M.D.s†
1919	181	
1920	330	3,047
1921	336	3,186
1922	445	2,529
1923	575	3,120
1924	611	3,562
1925	639	3,974
1926	748	3,962
1927	796	4,035
1928	842	4,262
1929	1,025	4,446
1930	1,074	4,565
1931	1,147	4,735
1932	1,241	4,936
1933	1,343	4,895
1934	1,550	5,035
1935	1,534	5,101
1936	1,547	5,183
1937	1,517	5,377
1938	1,522	5,194
1939	1,651	5,089
1940	1,812	5,097
1941	2,034	5,275
1942	1,833	5,163
1943	1,535	5,223
1944	1,194	5,134 + 5,169
1945	833	5,136
1946	948	5,826
1947	1,463	6,389
1948	1,947	5,543
1949	2,985	5,094

* Figures for 1919–27, inclusive, taken from "Reprint and Circular Series of the National Research Council—Doctorates Conferred in the Sciences by American Universities." Figures for 1928–49, inclusive, taken from *Doctoral Dissertations Accepted by American Universities*, published by H. W. Wilson Company, New York, and from the study of the science doctorates in the United States, conducted by the Office of Scientific Personnel of the National Research Council.

† *J. Am. Med. Assoc.*, **141**, 33 (1949).

and place of his proposed research. In the case of the Natural Sciences program, this material has already been screened by a fellowship committee of a council division, so that scientists of the applicant's own field may make recommendations and, particularly, subject his proposed work to searching consideration of its significance and of the degree of understanding and ingenuity it reveals. In the Medical Sciences program, where this preliminary screening is unnecessary, the board has in addition the benefit of an estimate obtained in a personal interview of the candidate by a member of the board.

At the meeting of the board, every scrap of pertinent information is used in making the decisions—the documents submitted by the applicant, the ratings of the screening committees, and the members' own estimates of the need for research scientists in the various fields. It may happen, for example, that a biologist with a particularly intriguing and significant research problem may be chosen over a chemist with a slightly better academic record. The board may also suggest to a candidate a more suitable institution for study in his field. It particularly discourages any impression that a fellowship is a convenient way to continue research at the school where the candidate has already taken most of his training—a kind of academic provincialism not in the best interests of scientific research.

With all the painstaking work by the board, however, the very nature of the problem of finding among young Ph.D.s and M.D.s our future research leaders gives the choice of awards the scientific standing of an intelligent guess—as, indeed, is almost any personnel selection problem with a long-range goal. Any criteria to determine the efficiency of the selection process are naturally obscured by the difficulty of evaluating the contribution of the fellowship, to say nothing of the difficulty of measuring research accomplishment. Nevertheless, scientists implicitly recognize a few yardsticks; one such is election to the National Academy of Sciences—a recognition of research leadership, and of the quality of publications. After the 1950 election, sixty-nine scientists chosen by the Fellowship Board were to be found among the academy members; among the fifty-five hundred applicants refused a fellowship there are five academy members. This score provides eloquent evidence on both the selection process and the influence of the research fellowship.

Once the wheels of the selection mechanism have turned, the successful applicant is assured of support for a year of research and study, with a chance for an extra year if his record warrants it. In the past, awards have been fairly evenly distributed between new appointments and one-year renewals, with a few fellowships continuing for three and even four years. In recent years, as the demand for the available fellowships became greater, renewals have been less common. There is not much variation by field in the average fellowship term of 1.50 years, with the notable exception of the figure of 1.83 years for physics. In general, the physical sciences have had slightly more renewals than the biological or medical sciences.

Fellows have studied in nearly one hundred and fifty universities and research institutions, with about 19 per cent going to foreign countries. Most of those studying abroad worked in Germany (6.5 per cent) or England (5 per cent), but twenty-four other countries are represented. As scientific research in America became stronger, the necessary teachers and facilities could be found at home, and the proportion of Fellows studying in Europe has declined.

The amount of money paid to a scientist during his fellowship studies has been reviewed by the Fellowship Board many times. It has always been the aim of the program to provide a stipend large enough to support the Fellow in reasonable comfort so that he can give his full time to research, and need not take on any teaching or other responsibilities. The cost of education and research have, of course, increased considerably over the years; but the stipend has always followed expenses quite well. There is in addition a travel allowance. In Figure 2 the average basic stipend—that is, the mean of the stipends for the natural sciences and medical sciences fellowships, for a man with no dependents—has been graphed on the same scale with a cost-of-living curve, as a semiquantitative indication of this parallelism. (See also Table 3.) Evidently if "a man cannot afford to take a fellowship"—a criticism often leveled at postdoctoral study—it is because the age at attainment of the degree, particularly since the war, is higher. The prospective Fellow is more likely to have a family, and although there is no fixed allowance for dependents, the extra amount has never been more than $600 for a wife and $300 for a child.

But statistics on stipends and length and location of study are incapable of illuminating the subtle process that occurs during the fellowship years. This process is the heart of the program, the best of the theory which successfully argued for decentralization of advanced training. Now, with his doctoral dissertation behind him, and much wiser in the difficult art of research, the Fellow goes to

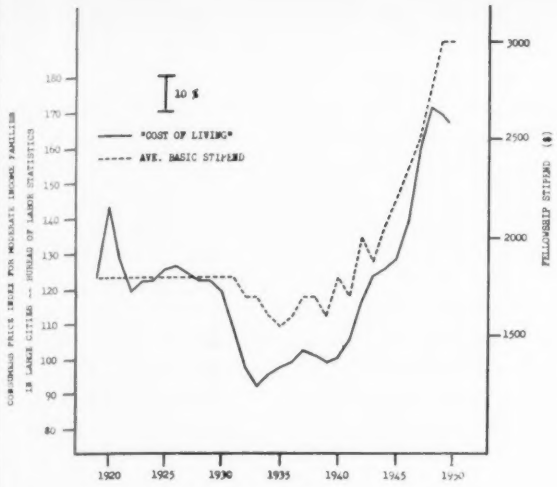

FIGURE 2.

live in the atmosphere of a new laboratory, free from the financial problems that plague graduate students, and free from the distracting load of teaching and paper-grading that is generally the lot of the young academic scientist. In the new laboratory his viewpoint is immensely broadened, and at the same time, as he sees more clearly, his own research interests become sharpened and focused. Nor is the training process one-way, for to his old, teacher's wisdom the Fellow brings new techniques—new electronic and instrumental tricks to biological research, modern mathematical weapons for stubborn chemical problems, a psychological insight for medicine. And the effect the newcomer has on the graduate students is powerful. He is of their age and of their training; he takes part in their seminars, and drinks four-o'clock tea with them. But he is a constant reminder that the doctor's degree is a means and not an end, for to them his command of the field is disturbingly thorough, and his suggestions so often steer their doctoral researches out of a theoretical or experimental impasse. Seeing a good scientist in action in this way has, without question, been the germ of many applications for National Research Fellowships. Thus even before their professional careers are fairly begun, the Fellows have been a stimulant to scientific research.

Over the years they have not lost the habit. The positions which men and women who were once National Research Fellows held in the spring of 1950 are summarized in Table 4. They are: "heads," 23 per cent; professors, 37 per cent; associate professors, 14 per cent; assistant professors, 8 per cent; instructors, lecturers, and minor academic positions, 5 per cent; researchers in federal and state government laboratories, 13 per cent; nonteaching institutional and academic research, including museums, hospitals, observatories, etc., 18 per cent (these scientists may also teach, in separate positions, but the duplication is not large except in the medical sciences); industrial research, 11 per cent; deceased or out of scientific work, 7 per cent (made up of about equal contributions from the two).

A "head," as used here, is a Fellow holding an unusually responsible position in scientific work. In a university, this would be a department head, or dean of science; in industry, a director of research, or vice president in charge of research and development; similarly, in government or institutional research, a research director, laboratory director, or senior scientist of a large project. A decision on the number of scientists whose positions are "unusually responsible" is arbitrary, but it is order of magnitude which is desired. Nearly one Fellow in four is a "head."

TABLE 3

STIPENDS AND COST OF LIVING

Year	Basic Stipend		Cost of Living*
	Natural Sciences	Medical Sciences	
1919	$1,800		123.8
1920	"		143.3
1921	"		127.7
1922	"	$1,800	119.7
1923	"	"	121.9
1924	"	"	122.2
1925	"	"	125.4
1926	"	"	126.4
1927	"	"	124.0
1928	"	"	122.6
1929	"	"	122.5
1930	"	"	119.4
1931	"	"	108.7
1932	1,600	"	97.6
1933	"	"	92.4
1934	"	1,620	95.7
1935	"	1,500	98.1
1936	"	1,600	99.1
1937	"	1,800	102.7
1938	"	"	100.8
1939	"	1,600	99.4
1940	2,000	"	100.2
1941	1,800	"	105.2
1942	2,200	1,800	116.5
1943	1,800	....	123.6
1944	2,000	2,100	125.5
1945	2,000	2,400	128.4
1946	2,200	2,500	139.3
1947	2,500	"	159.2
1948	3,000	"	171.2
1949	3,000	3,000	169.1
1950	3,000	"	

* *Consumers' Price Index for Moderate Income Families in Large Cities.* Bureau of Labor Statistics.

Nearly two thirds—64 per cent—of the Fellows are not hard to find; they are right at home in the centers of fundamental research and teaching, the universities and colleges.*

PRESENT ACADEMIC GRADES OF FELLOWS

	NUMBER		PERCENTAGE OF ALL	
Full professors	498		36.7	
(Including department heads)		158		12.4
Associate professors	195		14.4	
(Including department heads)		10		
Assistant professors	112		8.3	
Instructors and lecturers	61		4.5	
Total academic	866		63.9	

Although it appears that a high proportion of Fellows is helping to train other research scientists, we cannot be sure of this without examining the schools where they are teaching, for high productivity of Ph.D.s in the sciences, and M.D.s. For this purpose a study of the doctoral degrees granted in the sciences over the decade 1936–45 is available.† Institutions may be arbitrarily divided into three classes: "A" schools, those producing ten or more science doctorates per year over this period (this group includes thirty-eight universities and all medical schools approved by the American Medical Association); "B" schools, producing one to ten Ph.D.s per year (there are forty of these); and "C" schools, those which produced less than one Ph.D. per year or which do not give the Ph.D. For the 805 Fellows of professorial grades, the distribution is 79 per cent in "A" schools, 10 per cent in "B," 11 per cent in "C." More detailed data may be found in Table 5.

It should be remarked that the Office of Scientific Personnel study showed that students who eventually obtain science doctorates come about equally from small schools and large ones, so it is not to be inferred that teachers in "C" schools are not helping in the training of scientists. Doubtless many a student who is introduced to the art of research by a Fellow at an "A" school learned his fundamental science—and learned it well—from a fellow at a "C" school.

Unusually high concentrations of Fellows exist in several of the American universities which are among the most productive of young scientists. In 1950 there were twenty-seven at the University of Wisconsin, for example, including the dean of the graduate school, the head of the department and three other professors of genetics, the director of the observatory and professor of astronomy, and professors of zoology, botany, mathematics, chemistry, plant pathology, agricultural bacteriology, psy-

* For purposes of this study, only nationally accredited universities and colleges are considered. See Part 3 (Higher Education) of the *Education Directory* of the Office of Education, Federal Security Agency. Washington, D. C.: GPO (1949).

† *The Baccalaureate Origins of the Science Doctorates Awarded in the United States.* Office of Scientific Personnel, National Research Council, Washington, D. C.: 1948.

TABLE 4

PRESENT POSITIONS OF FELLOWS

No. of Fellows	Fields	Heads*	Professors*	Associate Professors*	Assistant Professors*	Instructor, Lecturer, etc. (Minor Academic)	Government (Federal and State) Research	Nonteaching Institutional and Academic Research, Including Museums, Hospitals, and Observatories	Industrial	Deceased or out of Scientific work	Total Duplications
126	Mathematics	25	70	23	14	2	2	6	8	2	26
16	Astronomy	5	3	4	3	0	0	4	1	2	6
196	Physics	58	80	19	2	2	41	11	31	10	58
229	Chemistry	64	64	22	17	1	25	11	76	16	67
15	Geology and Geography	3	2	3	3	0	4	1	2	1	4
164	Zoology	25	53	35	18	5	21	21	7	13	34
112	Botany	17	41	14	11	4	27	12	7	7	28
41	Agriculture	13	21	4	0	0	13	0	4	2	16
8	Forestry	3	3	0	0	1	3	0	1	0	3
27	Anthropology	5	8	3	2	3	5	4	0	2	5
93	Psychology	23	47	11	3	6	6	8	3	10	24
1,027	Natural Sciences	241	392	138	73	24	147	78	140	65	271
332	Medical Sciences	74	106	57	39	37	31	168	9	26	215
1,359	All	315	498	195	112	61	178	246	149	91	486

* In nationally accredited institutions only.

chology, agriculture, oncology, physiological chemistry, and medical microbiology.

There were twenty-one Fellows at the California Institute of Technology, including the president; the chairman of the division of mathematics, physics, and astronomy; the chairman of the division of biology; the head of the department of chemistry and three other chemistry professors; and professors of physics, mathematics, biology, electrical engineering, and genetics.

There were twenty-four Fellows at the Massachusetts Institute of Technology, including the dean of science, the heads of the departments of mathematics and biology, the head of the department and two other professors of chemistry, the director of the spectroscopic laboratory, the director of the acoustics laboratory, three professors of physics, and a professor of biophysics.

There were forty Fellows at Harvard University, including the heads of the departments of zoology, nutrition, psychology, and physical chemistry in the medical school; the director of the psychoacoustic laboratory and the director of the Harvard Forest; three professors of mathematics, two professors of physics, and professors of entomology, biology, physiology, botany, chemistry, psychology, biochemistry, pathology, and surgery.

At Cornell University there were twenty-five Fellows, including the heads of the departments of zoology, physics, and mathematics; two professors of psychology and two of surgery; and professors of geology, mathematics, physics, biochemistry, nutrition, medicine, pathology, and neurology.

At Columbia University there were thirty-five Fellows, including three professors of mathematics, two professors each in psychology, chemistry, and medicine; and professors of anatomy, bacteriology, surgery, neurology, pathology, and pharmacology.

On the Berkeley campus alone of the University of California, there were twenty-nine Fellows, including the heads of the departments of biochemistry and psychology, the director of the radiation laboratory, the director of the microwave laboratory, six professors of physics, two professors each of mathematics and botany, and professors of biostatistics, anthropology, chemistry, psychology, soil microbiology, physiology, plant pathology, and fruit technology.

National Research Fellows have done much more than just lecture about research. Fundamental research is so much a part of their scientific thinking that usually no amount of administrative or executive responsibility will take them entirely away from their laboratories. Probably the most generally applicable recognition of research accomplishment in this country is election to the National Academy of Sciences. Since the average age of election is fifty, and since the National Research Fellowship program has been in existence thirty years, it would be expected that only the first few years of the program have had time to produce academy members. Yet in 1950 there were sixty-five Fellows among the 237 members of the Academy who were under sixty and might conceivably have applied for a fellowship:

Section of Mathematics: A. A. Albert, Jesse Douglas, E. J. McShane, Paul A. Smith, Hassler Whitney.

Section of Physics: J. W. Beams, Chairman; S. K. Allison, R. F. Bacher, K. T. Bainbridge, Gregory Breit, R. B. Brode, A. H. Compton, E. U. Condon, L. A. DuBridge, E. O. Lawrence, E. M. McMillan, R. S. Mulliken, Alfred O. Nier, J. R. Oppenheimer, Julian Schwinger.

Section of Chemistry: P. D. Bartlett, A. C. Cope, Lyman Craig, Henry Eyring, R. C. Fuson, M. S. Kharasch, J. R. Kirkwood, L. G. Longsworth, J. E. Mayer, Linus

TABLE 5

FELLOWS IN ACADEMIC WORK

No. of Fellows	Field	Number in Teaching	Percentage in Teaching	Number in Professorial Grades	Percentage in "A" Schools	Percentage in "B" Schools	Percentage in "C" Schools
126	Mathematics	109	86.5	107	65	15	20
16	Astronomy	10	62.5	10	80	10	10
196	Physics	103	52.6	101	78	13	9
229	Chemistry	104	45.5	103	78	14	8
15	Geology and Geography	8	53.3	8	50	25	25
164	Zoology	111	67.7	106	79	9	12
112	Botany	70	62.5	66	74	12	14
41	Agriculture	25	61.0	25	64	24	12
8	Forestry	4	50.0	3	100	0	0
27	Anthropology	16	59.2	13	54	31	15
93	Psychology	67	72.0	61	64	15	21
1,027	Natural Sciences	627	61.1	603	72.8	13.7	13.5
332	Medical Sciences	239	72.0	202	97	1	2
1,359	All	866	63.8	805	78.9	10.5	10.6

Pauling, W. H. Rodebush, George Scatchard, M. L. Wolfrom, L. F. Small, O. R. Wulf, D. M. Yost.

Section of Geology: G. G. Simpson.

Section of Botany: G. W. Beadle, James Bonner, R. A. Brink, P. R. Burkholder, J. N. Couch, David Goddard, Barbara McClintock, L. J. Stadler.

Section of Zoology and Anatomy: Malcom R. Irwin, F. O. Schmitt, T. M. Sonneborn, Victor C. Twitty.

Section of Physiology and Biochemistry: E. G. Ball, D. W. Bronk, E. J. Cohn, Vincent du Vigneaud, C. A. Elvehjem, H. K. Hartline, J. L. Oncley, Homer W. Smith, W. M. Stanley, George Wald.

Section of Anthropology: Leslie Spier.

Section of Psychology: S. S. Stevens, B. F. Skinner.

Deceased: W. E. Bachmann, W. W. Hansen, Selig Hecht.

The importance of the health and growth of scientific research to the nation's defense was clearly recognized at the very beginning of the fellowship plan. Certainly wartime service, either in the armed forces or in scientific research on military problems, is a very direct way in which a scientist may contribute to his country's welfare, although it is not the only way. If the fellowship program grew out of the weakness of research in America which World War I had underscored, then World War II provided dramatic proof that the situation had been remedied, and that the fellowships had helped; for Fellows were scattered in key positions all through the staffs which developed such near miracles as the atomic bomb, efficient radar and radar countermeasures, and the proximity fuse.

Almost one half of all National Research Fellows contributed their talents to the prosecution of World War II. Many served as officers of the armed forces; others joined large government-supported research centers in different parts of the country; and many who stayed at their universities or industrial laboratories abandoned their own research program and worked on military problems. And one medical Fellow out of three was in uniform.

The development of atomic energy for military purposes in three or four years was undoubtedly the most spectacular wartime accomplishment of the scientists. This project provides a good example of the contributions of National Research Fellows to war research. World War II has been called the "physicists' war," and, correspondingly, the physicists among the Fellows had the greatest representation in war work—about 65 per cent. Of far more significance than this figure, however, is the positions which Fellows held. Under the OSRD and, later, the Manhattan District, the thirteen-man group guiding the uranium work included seven Fellows: A. H. Compton, E. O. Lawrence, S. K. Allison, J. W. Beams, G. Breit, E. U. Condon, and H. D. Smyth. At the Los Alamos Laboratory, at the culmination of this tremendous scientific effort, three more Fellows held key positions—J. R. Oppenheimer, the director of the Laboratory; Robert F. Bacher, who was charged with the assembly of the heart of the first atomic bomb; and Kenneth T. Bainbridge, who was in charge of its detonation. These men were among the scientists lying inelegantly on their bellies as the bomb flared weirdly over the New Mexico desert in the somber dawn of July 16, 1945.

The appearance of the atomic age upon the stage of human history dramatized to anyone who could read a newspaper the accomplishments of the ordinarily self-effacing research scientist. No one now needs to be convinced that the scientist is a powerful ally in man's struggle to better his living and insure his freedom. But just as we could not have predicted twenty years ago that the theoretical physicist would be today's hero, so we cannot predict what science will be the strength or salvation of the future. It may be physiology, or bacteriology, or perhaps cultural anthropology. We shall always need superior minds well trained in the techniques of establishing new facts—and, to a greater extent, trained with a societal awareness that wise action may sometimes be suggested by new facts.

Any efficient device which will provide a continuing supply of these unusually competent and valuable citizens is virtually dictated to our society as an investment for its future. A broad hint for the training of leaders in any field is afforded by the history and the emerging pattern of results of the National Research Fellowships.

Heat and Mass Flow Analyzer

V. PASCHKIS

Victor Paschkis was born and educated in Vienna (Sc.D., Institute of Technology, 1923). He suggested to Columbia University the erection of the Heat and Mass Flow Analyzer Laboratory, designed it, and is at present its technical director. He worked as an engineer in various European countries until 1938, and until 1940 in the field of industrial electric furnaces in the United States. He is the author of Industrial Electric Furnaces and Appliances *(2 vols., 1945, 1948).*

HEAT and the laws of heat exchange or heat transfer enter into almost all life's problems. The earth receives heat by radiation from the sun. The human body generates heat as long as it lives, and thus the heating of our homes has to contribute only the difference between the heat generated by the inhabitants and the heat losses to the cold air outside. One of the first signs of a decaying tooth is that of improved heat transfer from cold or hot food to the nerve, sensed as pain. Similarly, almost all products of our technology involve a thermal process at some time or other.

Metals are heated so that they may be cast either into the shape of their ultimate use or in ingots that must be heated again for further processing. The manufacture of plastics involves several heating and cooling processes. Ceramic material is "fired." All the processed foods—pasteurized milk, cereals, bread, all canned victuals—have undergone at least one heat process.

In production processes, such as pressing, turning on a lathe, or drilling, heat is a problem because it is generated during the deformation of the material. This sort of problem involves "heat flow." If the brakes in a car are jammed down or are operated on a hill, heat is generated; and many an accident has occurred because the heat generated in "drag-braking" on a hill has burned out the lining so that at the bottom of the hill there was not enough braking power left to bring the car to a stop.

It is, then, not surprising that a science with so wide an application is a highly developed one. This development refers to the basic laws only, however. Applications to practical problems are difficult because they almost always involve combinations of several basic laws, and these combinations frequently are not known. Mathematical solutions for any but the most simple cases become quite complicated and require a knowledge of mathematics on a level not commonly available in the engineering field. But even where a mathematical solution is possible, it is often so time-consuming as to make application, at least in industry, impractical. Yet the problems of heat transfer must be solved if the various branches of application (metallurgy, ceramics, rubber, plastics, etc.) are to be developed from their present state of being mainly an art and put on a more rigid quantitative basis: more accurate knowledge of the thermal aspect of the problems is a necessary, but in general not a sufficient, condition for achieving this goal.

Exploration of heat-transfer problems is possible by direct experimentation or by computation. Direct experimentation involves temperature measurements and measurements of the rate of heat flow. The inherent difficulty in any measurement is that every measuring device changes the conditions to be measured. This difficulty is often particularly serious in thermal measurements. Moreover, computation of corrections which are, for example, very simple in electric measurements is quite difficult in thermal measurements. The use of computing devices, which play a large role in modern research, therefore seems a desirable method of solving such problems.

The field of computing devices has grown mushroomlike over the past fifteen to twenty years. One class, described as "digital computers," has received wide publicity in general magazines and the scientific press. The Eniac has probably received the greatest publicity. Essentially these devices carry out at very high speed the common operations of addition, subtraction, multiplication, division, raising to a power, and taking roots. In addition, they can be equipped with a "memory." But they can only evaluate equations that have already been solved.

Although digital computers can and are being used for heat flow problems, another class, called "analog computers," is more generally adaptable for this purpose. One of the latter type, the Heat and Mass Flow Analyzer, has been in use for more than ten years. The basis for the application of this computer to heat flow analysis is given here, with comments on the technique of its use.

It happens that groups of phenomena in quite different fields can be expressed by the same mathematical equations. This fact may point to some more general relationships not fully understood by scientists at present. But even though the fact may not be understood, it can be put to good use. Take for example a rod (Fig. 1), which is assumed to be completely insulated on its sides. Initially the rod is at uniform temperature throughout. Now, expose the two ends suddenly to a temperature difference. Then the temperature rise at different points in the rod can be calculated accurately, based on equations developed by Fourier, the father of the science of heat transfer. The only requirement is that the thermal properties of the rod do not change either with temperature or with time. Figure 1*a* shows some curves that indicate schematically the temperature rise at different points of the rod.

Let the same Figure 1 represent a noninductive electric cable, the electric properties of which do not change with the voltage. Let the cable be initially at zero potential over its entire length. Then suddenly impose on the ends of the cable a potential difference. This will cause a change of potential at all points on the cable. This change of potential with time can be calculated accurately. The equations describing the potential change are the same as those describing the temperature change in the case of the rod.

An equation—differential or other—of course comprises only arbitrary symbols. If it is said that the equation describes two different phenomena (temperature change and change in electric potential) then it should be understood that the same symbol in the equation designates two different magnitudes, one for each of the two processes.

In Table 1 the equivalent magnitudes used in the equations and one consistent set of dimensions for each of the two processes are shown.

Obviously, by observing electric phenomena on an appropriate cable, one can find the answer to the thermal problem in the rod. However, to find for every thermal problem the equivalent electric cable would be exceedingly difficult. Therefore a technique is used that is common practice in certain branches of electrical engineering; it is referred to as "lumping." This process consists of two steps: first, think of the body (here the cable) being composed of a finite number of sections or lumps. Second, in each section or lump consider the properties concentrated in axis and center rather than evenly distributed, as they actually are.

In Figure 2 the same cable is shown as in Figure 1. It is assumed that it is divided into 4 lumps of equal size. Each lump, then, is a cylinder of diameter D and length L. The capacity, which is actually evenly distributed over the entire material, is thought of as concentrated in one capacitance, located at one half of L from either end. The resistivity, which is actually evenly distributed over the entire material, is thought of as concentrated in one resistance, located in the axis of the cylinder. Thus one lump (Fig. 3*a*) of the rod is represented by a resistance and a capacitance, connected as in Figure 3*b*. The total cable, then, is represented by a circuit (*network*, Fig. 4); and inasmuch as the equations for the cable and the insulated rod are

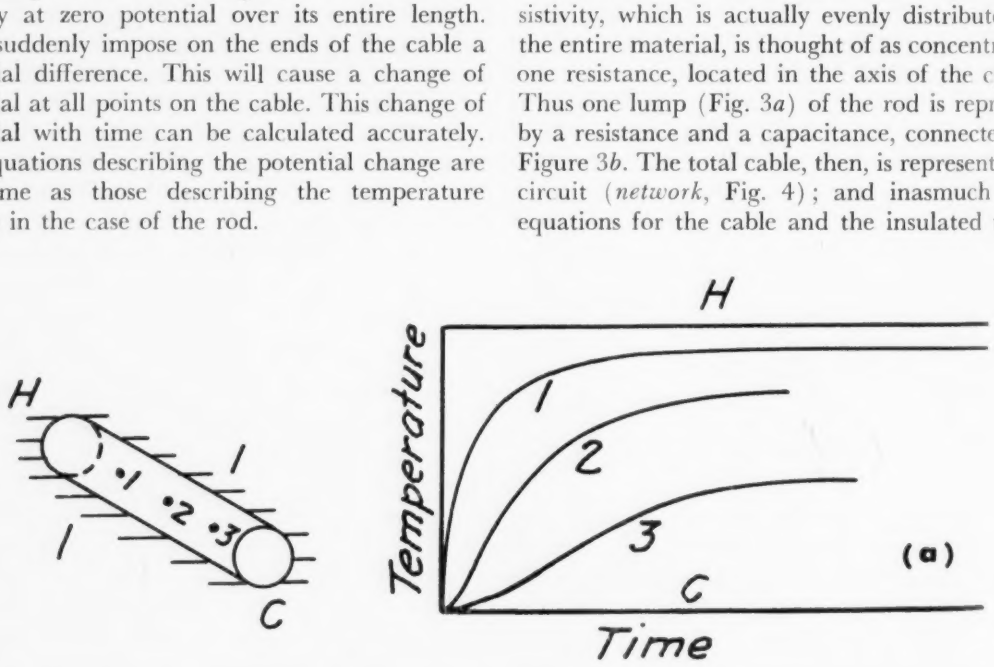

FIG. 1. Insulated rod. *I*, insulation; *H*, hot side; *C*, cold side. *a*, Schematic temperature rise in the insulated rod. Curve C, cold surface; Curve H, hot surface; Curves 1, 2, and 3, temperatures at points 1, 2, and 3, respectively.

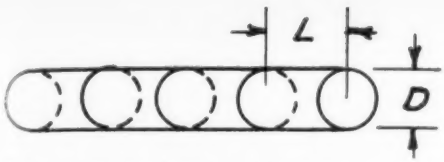

FIG. 2. Insulated rod divided into sections.

identical the circuit in Figure 4 can be said to represent the rod also. The resistivity and capacity of the fictitious cable used to calculate the network are called "network constants." They must be calculated for each thermal problem based on the dimensions of the body, as well as its thermal properties (thermal conductivities, specific heat, etc.).

If we think of a rod of very small diameter (e.g., a long, thin wire) then there is no difficulty in accepting the concept of uniform temperature over the cross section of the rod (wire). In increasing the number of lumps for a given total length of the rod, the length of the individual lump must obviously decrease. If this increase in number of lumps is carried very far the length of the individual lump becomes infinitely small, and the lumped circuit approaches more and more the cable with evenly distributed properties.

By exposing the circuit in Figure 4 to certain potentials, or by introducing currents, any desired thermal occurrence may be represented. For example, if the ends of the rod (which was initially at constant temperature) are raised to a constant temperature difference, in the analogous electric experiments a constant voltage is suddenly applied to the ends of the circuit. It will be remembered that a voltage increase corresponds to a temperature rise. If the rod is heated by internal heat sources, such as exothermic chemical reaction, current passing through a metallic rod, or dielectric heating applied to a nonmetallic rod, the heating still can be represented on the analog computer: current is fed in at each lump, as indicated in Figure 5, the current being proportional to the productivity of internal heat sources.

So far only "one-dimensional heat flow" has been considered. Because the rod was completely insulated on the sides, the heat flow occurs only in

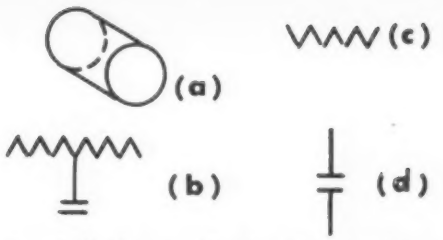

FIG. 3. *a*, Individual section of rod; *b*, circuit representing one section; *c*, symbol used for electric resistors; *d*, symbol used for electric capacitors.

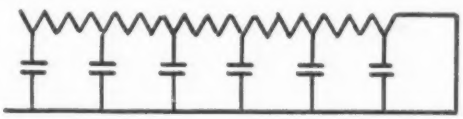

FIG. 4. Network representing insulated rod, Fig. 1 or 2.

the direction of the axis of the rod and therefore is called "one-dimensional." Theoretically, one-dimensional flow can never occur, because there is no "perfect insulation" for the sides. Actually, cases where one-dimensional flow is even approached are seldom found in nature. But the analog computer technique is not limited to one-dimensional flow. The equations for two- and three-dimensional heat flow and the two- and three-dimensional distribution of electric current in an electric conductor of the same shape as the body subjected to heat flow are again identical. To illustrate the concept of two-dimensional flow, consider Figure 6, showing the cross section through a bar of great length (no end effects); the bar is heated on one face, and cooled on the three others. Heat will flow from the hot side to the three cold sides, as indicated by the lines, not only perpendicular to the heated face, as in the case of one-dimensional flow, but at various angles, in a two-dimensional pattern. But we can now divide the body again into sections, this time into groups in two directions. It is not possible to provide resistors for each of the infinite number of directions in which heat can flow in the bar. Therefore a system of rectangular coordinates is introduced (Fig. 7), and the resistances are concentrated in the two directions, as indicated in Figure 7*a*, which shows a network called two-dimensional

TABLE 1

Thermal System		Electric System	
Magnitude	Dimension	Magnitude	Dimension
Thermal resistivity	foot, hour, F/Btu	Electric resistivity	megohm × foot
Thermal capacity (Volumetric specific heat)	Btu/cu ft, F	Electric capacity	microfarad/cu ft
Temperature difference	F	Potential difference	volt
Rate of heat flow	Btu/hour	Current	microampere
Heat content	Btu	Stored electricity	microampere-second
Time	hour	Time	seconds

because resistors are provided for flow in two directions.

Similarly, if heat flow occurs in three directions a three-dimensional network as in Figure 8 can be used. There are several advantages in using an analog computer, such as the Heat and Mass Flow Analyzer, for heat flow studies. On the computer it is possible to separate variables. Say that four or five variables enter into a process. In nature it is very difficult to vary the individual variables at will because all too often they are interdependent. If one is varied the others change too. On the analog computer it is possible to control the individual variables at will and make changes in only one of them. Moreover, in studying basic questions of heat transfer by means of actual experiments, it is impossible to eliminate the effect of extraneous heat losses, because not even an approximately perfect heat insulation is known. In the electrical computer circuit, it is possible to provide a practically complete insulation, even if at times this entails difficulties, particularly when working with very small currents or with changes in a very slow time cycle. Even in the worst case, however, the leakages are negligible as compared with thermal leakages in direct experiments. Thus the analog computer permits study in great detail of "ideal processes," which are not subject to any heat loss. Such study is invaluable to the understanding of a process.

There is still another fascinating and important feature of the analog computer technique. It was stated above that the equations for the cable, and therefore indirectly for the network circuit, are identical with those for the rod. By proper selection of the network constants it is possible to introduce a time scale. A thermal occurrence happening in a fraction of a second may be reproduced on the analog computer in 10, 15, or more minutes, and, conversely, thermal occurrences taking thousands of years, such as geological events, may be represented in the electrical experiments in half an hour or less. Moreover, if at any time it is desired to stop the experiment—stop an "explosion" after it has started—a simple throw of a switch can do so.

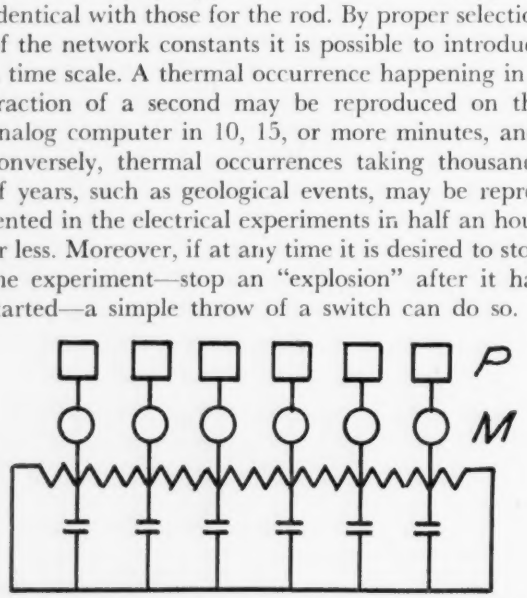

FIG. 5. Circuit used to study rod heated by internal heat sources. *P*, power supply; *M*, milliamperemeter.

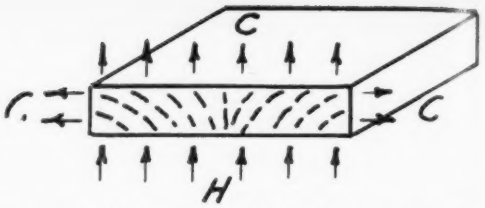

FIG. 6. Slab is heated on side marked *H* and cools to sides *C*.

The analog computer that performs all this work is the outgrowth of an idea of a Dutch engineer, C. L. Beuken, who, more than fifteen years ago, conceived the idea and developed a small apparatus. The present development covers a room of 700 square feet, comprises thousands of resistors and condensers and tens of thousands of feet of wire. Figure 9 gives a partial view of the equipment. In addition to the basic elements mentioned, many other instruments are being used, some more or less standard in electrical laboratories, some especially devised for the purposes of the laboratory. The outsider might be overwhelmed by the number of electrical connections to be made, and each connection in a circuit is a patent source of error. It would thus appear that if errors occur it might take a long time to locate them. Over the years, however, our laboratory has developed techniques for the detection of errors within a very short time range, usually from a few minutes to a maximum of half a day, and, with growing experience, fewer and fewer faults occur that need detection.

It is obvious that the field of application of such computing machines is almost unlimited. This laboratory has been in continuous use since its installation more than ten years ago, the only interruptions being when the facilities were twice increased, calling for a temporary shut-down. Out of the many applications dealt with to date the following may be of some interest. Any object used at elevated temperatures should be insulated if at all possible. Failure to use insulation means wasting fuel. Insulation, however, costs money, and therefore there is a limit to how much insulation is applied; with increasing thickness of insulation heat losses decrease, but the amount to be spent for the insulation increases. By expressing the heat losses in dollars and cents (based on the fuel cost), it is possible to find out what thickness of insulation involves the smallest over-all cost. If the insulated object is not at elevated temperature continuously but only intermittently, the savings in heat losses obviously go down. Steam pipes in office buildings that are not heated around the clock are an example of such intermittent use of insulated

objects; or heat-treating furnaces used only during one or two shifts in the factory. Calculation of the heat losses under such conditions is a major problem, which because of the time involved, has previously not been solved. Tables for such heat losses have been set up on the computer for various combinations of conditions.

Casting of metals is a very old art, and only in fairly recent years have attempts been made to put foundry work on a more scientific basis. Although the entire foundry process is closely linked with heat-transfer problems, there is probably not a single foundry employing a heat-transfer specialist. But cooperative research to investigate the fundamentals of heat transfer as applied to foundry work has been sponsored by the American Foundrymen's Society for the past several years and has resulted in important information.

Everyone is conscious in a practical way of the field of automatic process control. The thermostats that maintain room temperature at a comfortable level, or the temperature controls used to protect automobile motors, the level control by which a toilet tank is refilled, are examples in point. The field of automatic control is mathematically identical with that of servomechanisms, which have recently received so much attention through Wiener's application of the methods to a broad field, and his creation of almost a new science called "cybernetics." The analog computer is being used successfully in studying solutions of problems in automatic control that are beyond the reach of present-day mathematical methods.

The heat generation between wheel and brake shoe or disk and disk lining of an airplane brake is almost inaccessible to actual measurement. But analysis on the analog computer has been simple and has been done in several instances.

In most industrial investigations the heat-transfer problem solved on the analog computer or otherwise yields the answer to but one side of a many-sided problem. In many cases the individual steps are small and of interest mainly to the expert. They form part of a long-drawn-out search for truth in a specific field and may yield complete answers only after a long period. However, one example may be described in some detail to show how a problem is handled on the analog computer.

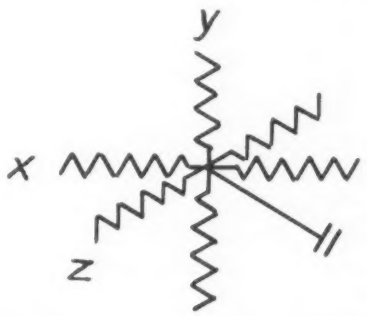

FIG. 8. Resistors for one section of three-dimensional problem; x, y, z represent resistance to heat flow along three axes of a three-dimensional coordinate system.

When a motion-picture film is being run, each part of the film is exposed to the projector arc only during a small fraction of a second. The film strip does not run continuously but, rather, stops at frequent, regular intervals, with a different picture in front of the projector lens. Normal projection speed is 24 frames/second. The projector arc burns continuously, but light is admitted to the film only intermittently; a mechanical shutter interrupts the path of radiation, and only when the shutter is open is the light projected through the film on the screen. Each picture on the film strip is projected twice, the shutter opening, closing, and opening again, so that although only 24 different pictures are projected each second 48 images are actually flashed upon the screen, each flash having a duration of 1/96 second. All these movements and the movement of the film strip are so rapid as to convey the picture with the movements perceived by the spectator. Notwithstanding the very brief time of exposure, the film may reach a high temperature, because the projector arc is radiating from a ball of incandescent gas in the crater at temperatures from 3,400° to 6,200° C. In connection with a study of the optical properties of projection, it was desired to know the change of temperature distribution in the film during and immediately

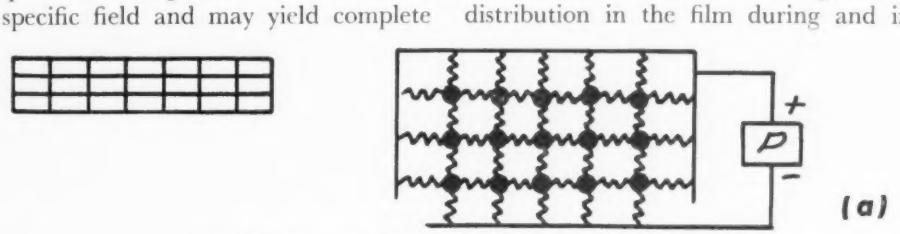

FIG. 7. Cross section of slab, Fig. 6, with indication of sections or lumps. *a*, Circuit representing slab, Fig. 6. Heavy dots at intersection of resistors represent capacitors. *P*, power supply; +, positive pole; −, negative pole.

after exposure to the arc. For a process lasting so short a time it is obviously not possible to apply a temperature-measuring device to the film: it would be neither practical to stick a thermometer on a film nor to place a thermocouple in it. Here the analyzer seems the only possible way of determining the temperature. A motion-picture film consists of a base and an emulsion, and for ordinary black-and-white film the emulsion carries deposits of black silver of varying opacity which modulate the passage of light and thus produce the black-and-white picture. As radiation from the light source hits these darkened spots the radiation is absorbed and generates heat. Thermally, a picture as in Figure 10 applies. The film strip during its short stop in front of the projector becomes heated, and part of the heat flows lengthwise from the picture under exposure to the preceding and following pictures; some heat is also conducted widthwise into the film from the metal of the projector gate, which is heated by spillover radiation from the arc, and which is in contact with each edge of the film. (These lengthwise and widthwise heat flows are disregarded in Fig. 10.) Figure 10 shows the two layers of the film, base and emulsion; the problem is to find the temperature distribution as a function of time for various rates of heat generation. The emulsion is not blackened uniformly over its entire thickness; rather, blackening varies with depth, dependent upon the darkness of the image plus the methods of printing and processing. While the absorption is thus distributed over the depth of the image and should be represented by some function of the distance from the emulsion surface, for simplicity in this problem such a function was replaced by an equivalent total absorption in a single plane. Several different assumptions were made to represent different distributions of the silver image in the emulsion.

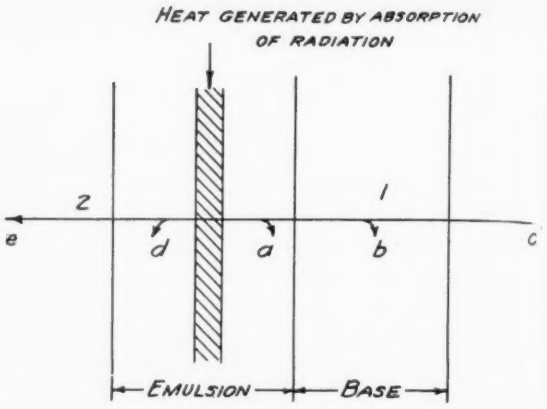

FIG. 10. Schematic drawing of film. Shaded area in the "emulsion" indicates blackened part of the emulsion in which radiation is transformed into heat. The heat flows in two directions, indicated by arrows 1 and 2. Part of heat flow 1 is used to heat up the emulsion between the blackened layer and the base (a), another part to heat up the base (b), and the remainder flows from the surface of the base to the surrounding air (c). Similarly, part of heat flow 2 is used to heat up the emulsion between the blackened area and the surface (d). The remainder flows through the surface to the surrounding air (e). The magnitude of all amounts of heat flow a–e vary with time. If steady state should be reached the amounts a, b, and d would become zero, and the entire heat generated in the blackened area would flow to the surrounding c and e.

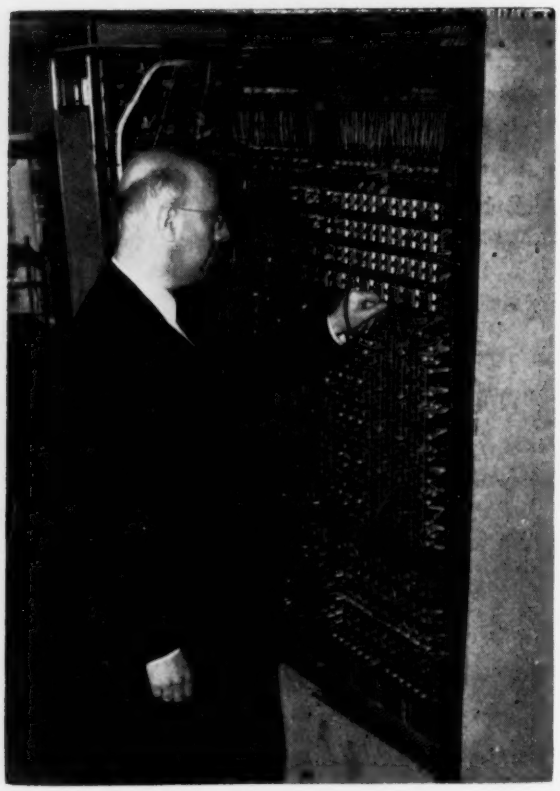

FIG. 9. Partial view of computer.

In order to represent the problem, both layers were thought of as divided into sections, or lumps, and a circuit was built essentially as shown in Figure 11. The circuit shows two parts, one each for base and emulsion, with a resistor and a capacitor for each section of each element, the capacitor being connected to the center of the resistor. The film loses heat to the air from both surfaces; these heat losses are represented by appropriate resistors on either end of the circuit. Heating takes place only over a short time. But after that heating is completed—that is, after the shutter prevents additional radiation reaching the film—the temperature in some parts will still rise because of heat storage in adjacent parts. Figure 12 may serve as example of such temperature curves. It is interesting to note that the length of the individual ex-

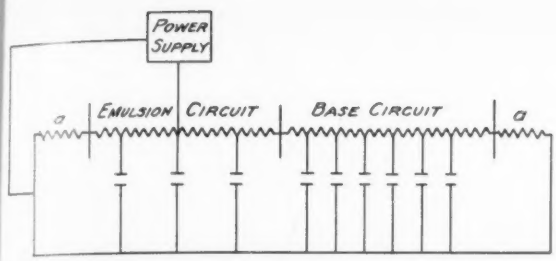

FIG. 11. Schematic circuit for representing the film problem. As shown, the blackened area is assumed to be in the center of the emulsion; if it were in the first or third section, the supply would be connected to the first or third capacitor instead of to the second.

periment on the analog computer is of the order of magnitude of six minutes, or 3.6×10^5 times as long as the actual exposure of the film.

The resulting temperatures were fairly high, but there was no way to check them. Years after the original investigation, Eastman Kodak developed other techniques for study of the problem and found that the best experimental evidence confirmed the order of magnitude of the temperatures predicted by the analog computer. In a summary of this problem it was stated

> What actual temperature the film reaches during projection is an interesting question that has never been answered satisfactorily. Obviously . . . the limitation of the size of the film makes direct experimental measurement extremely difficult. A number of estimates have been made, however, and perhaps the best by that of the electric analogy method. . . . The accuracy of these values theoretically is limited only by the accuracy of the necessary assumptions that must be made in setting up the problem.

Besides solving such individual problems, the analog computer has an important place as a straightforward calculating machine. If industry is to solve heat problems systematically rather than haphazardly, the engineer in the field must have charts and tables that give him answers to problems as soon as they arise. The analog computer is a convenient way to produce such charts and tables. Computation by conventional mathematical means or direct experiment (temperature measurements) takes too long and generally is beyond the reach of the man in industry.

There is no tool of scientific endeavor known that does not have its limitations. The limitations of the analog computer may be classified in two groups, one being common to all computational techniques, the other being inherent in the analyzer. The first group comprises errors because of insufficient knowledge of thermal properties to be used in setting up the computer. The results obtained are in no instance better than the values of the thermal properties involved in the problem, which are used to set up the circuit. Say, for example, that for a certain body the thermal conductivity is 2.0 but, either because of lack of knowledge or because of inattentiveness, a value of 1.5 is used to calculate the computing circuit. Obviously the results obtained will be wrong. The values of the thermal properties are all too frequently not well known. The reason for this is that up to the time of the analog computer there was not enough demand for knowledge of thermal properties, because no practical means of computation was available. The analog computer can, however, turn this disadvantage into an asset.

As mentioned above, it is possible to change at will on the analog computer the different variables involved in a process. Usually the possible values of the properties are known within certain limits, even if these limits are quite wide. By carrying out the computations on the analyzer repeatedly, using the different limits of the variables, one can find out which of the several variables (properties) has a determining influence on the results. Knowledge of which properties are important contributes largely to an understanding of the process and opens the way for improvements.

The second group of limitations comprises those inherent in the analyzer. First, results obviously depend on accuracy and maintenance of the units (resistors and capacitors). Inaccuracies and faulty elements will spoil the computations. If the boundary conditions that are to be imposed become too involved, simplifications may have to be used in building the computing circuit. And, finally, there is a limitation due to shape. If the shape of the body to be investigated is irregular, a large number of sections is required for adequate representation.

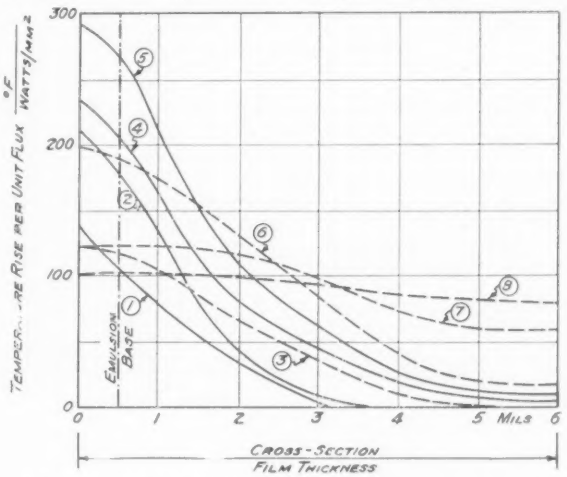

FIG. 12. Schematic indication of temperature-space-distribution. The various curves 1–8 are drawn for different times after start of exposure.

In this case the circuits may call for so many connections that they become practically unmanageable. A modification of the technique has therefore been developed. A mold is made of the shape of the body in which heat flow occurs—for example, a mold of the rod shown in Figure 6. The mold is filled with a liquid resistance medium, and electrodes are connected at the different points where heat flows in or out of the body. Figure 13 is an example of such a mold with the electrodes attached. Leads are inserted into the tank and connect on the outside to capacitances. The liquid resistance medium represents the continuous body subject to heat flow. The capacitances represent, as before, the heat storage capacity of the body. Thus the resistor network used before and shown by way of example in Figure 7*a* is replaced by a means capable of representing any complexity of shape. By this method the limitation of the original analyzer has been overcome. It may be noted that in some instances a combination of the two methods—that of the mold with liquid resistance and that of a resistance network—may be used.

In early technology there was almost no division between pure and applied science. The men who discovered the basic principles of physics or chemistry were also leaders in what would today be called "engineering" and, incidentally, often also in philosophical endeavor. Leibnitz and Carnot are good examples in point. But with the coming of the industrial age the need for technological improvements was far ahead of scientific discovery, and men built by experience more and more complex machinery. When the call for refinements and improvements of a product or process arises it is frequently found that scientific understanding of the process is lacking. This is not surprising, for if we look at any process or product, we shall find many branches of science contributing to its success. And the technologist in any one field is so engrossed in his work that he lacks the detachment to see the individual contributing problems.

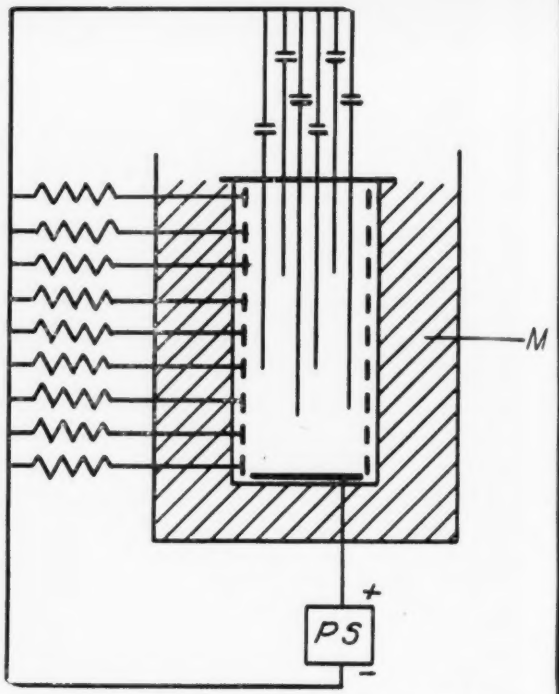

FIG. 13. Schematic drawing of mold. Outside resistors are used for boundary conductance and capacitors to represent storage. *M*, mold; *PS*, power supply.

The Heat and Mass Flow Analyzer will contribute to bringing one of these branches of science —heat transfer—to a point where it will be usable for industry, thus decreasing the gap between theory and practice.

THE brightest flashes in the world of thought are incomplete until they have been proved to have their counterparts in the world of fact.

—JOHN TYNDALL, "Scientific Materialism" (in *Fragments of Science*, Vol. 2)

Bright Future

EMILY ERICSSON

Miss Ericsson's previous appearance in our pages was in the July 1950 issue, when we published her "Little Land," a discussion of Portugal and her people. She is now living in the United States, after having been Assistant Financial Attaché, Embassy of the United States at Lisbon.

PRACTICALLY unknown to the world before the war, little known even today, the Portuguese colony of Angola is nonetheless a region of prime importance. It is of great strategic interest because of its location, climate, and natural wealth. It is of great economic interest because of its settlement possibilities. The future of Angola lies in its colonization, and fortunately it presents conditions somewhat analogous to those of the European lands from which settlers have been, and will continue to be, drawn.

Angola is located on the western coast of Africa, between parallels 4° 21′ 26″ and 18° 02′ 10″ South and has a total area of 481,266 square miles. It is bordered on the north by the French and Belgian Congos, on the east by the Belgian Congo and Northern Rhodesia, on the south by Botolandia (formerly German South-West Africa), and on the west by the Atlantic Ocean. With these boundaries, and in accordance with the Luso-Belgian Agreement of January 3, 1928, ratified by the government of the Metropole on March 21 of the same year, Angola occupies Cabinda, Malembo, and Massabi—three territories accorded her previously by the Belgian Conference of 1885.

South-central Africa, in general, forms a vast plateau some 3,000–5,000 feet high, and usually rises from low-lying shores. Angola shares the general conformation of the continent and has a maximum altitude of 7,700 feet. It may be considered as falling into three zones: the Coastal, the Intermediate, and the Planalto, or Plateau. The Coastal zone is 60–90 miles wide, and the land rises gradually to the interior in successive waves. It is a region of dunes, hills, and gradual elevations interspersed with ocean-level areas. The Intermediate zone presents the most uneven terrain in the entire colony. Here are the Zaire, M'Brige, Cuanza, Lucala, and Cunene waterfalls; the mountains show volcanic activity. In the north, near Damba, Maquela do Zambo, and Bungo, the altitude is approximately 4,000 feet. To the east of Malanje, the Serra de Talamungo reaches a height of 4,400 feet, then drops sharply into the fertile lowlands of Cassanje. The highest land lies between Ganda (Vila Mariano Machado) and Huambo (Nova Lisboa); the highest settlement is at Vila Nova, 6,000 feet above sea level. The Intermediate zone is followed by the Planalto—the great plateaus of Malanje, Lunda, Bié, Moxico, Huila, and Benguela. In the east these plateaus form the Congo-Zambezi watershed; in the west they form the divide between the Cuanza River to the north and the Cubango and Cunene rivers to the south. The entire Planalto lies above 3,000 feet, although a drop in altitude will be noted as one travels from south to north in Lunda; from west to east in Moxico; from northwest to southeast in Bié, following the basins of the Cassai and Cuango rivers, the Zambezi River, and the Cuando and Cubango rivers, respectively.

The rivers of Angola are numerous, and many are navigable. A study of the hydrography of the colony shows great possibilities for development of hydroelectric power, irrigation, and communications, despite the fact that in certain sections the water is brackish because of the composition of the soil, and that along the coast many so-called rivers such as the Bero, Caroca, and Corporolla are, in reality, dry stream beds except during the rainy season. The most important rivers rise in the Planalto: the Cuango and Cassai, which flow to the north and empty into the great Zaire, or Congo; the Zambezi, which rises in the highlands of Angola, crosses British territory in South Africa, and empties near Beira, Mozambique; the Cubango and Cuando, which flow across the extreme southeast of Angola; and the Cuanza and Cunene, which flow into the Atlantic. As the slope of the land in the Planalto is generally abrupt to the west and gradual to the northeast, east-west rivers, with the exception of the Cuanza and Cubango, are small and rapid, in keeping with the land formation.

Navigation along the Angolan coast must still be

by sight; the force and direction of the currents are variable, and the system of lights is very poor. Added to these drawbacks is the lack of maps and the hazard of fog caused by the cold Benguela Current of the Antarctic Ocean, which washes the coast. Nevertheless, navigation is not too difficult even under present conditions, as there is continuous calm; development of a great shipping industry is possible, for Angolan ports are, in certain respects, magnificent—especially in security of anchorage and in facility of adaptation to commercial uses. In the Baia dos Tigres, for example, all the squadrons of the world could lie at anchor, and Lobito and Luanda are shelter ports of the best type. This great natural advantage is of great importance, for the location of Angola makes her the natural outlet of much of interior Africa. From Chilongo, in the center of the mineral basin of Catanga, to Southampton the route via Lobito is 3,553 miles, 2,719 miles shorter than the routes via Beira, Mozambique, and Capetown.

Communications in Angola today are fairly well developed, but they are far from adequate, and any increased economic activity—such as that in mining and lumbering under study by the Economic Cooperation Administration—will necessitate considerable improvement. There are at present some 22,000 miles of first-, second-, and third-class roads, and four main railway systems. The Luanda and the Mossamedes are state-owned; the Amboim and Benguela are private enterprises. The Benguela Railway, built in 1905, runs to the Belgian frontier and was planned to carry the important export traffic of the Catanga to Lobito, the natural port of the region. A second railway—the Luanda-Umbaca-Malanje—is also designed to share the traffic of the Congo basin, and if the Congo is greatly developed Luanda will become important, but prolongation of the railway to the east, aiming at an eventual junction with the Congo system is not at present justified. State-owned airways were first provided for in the budget of 1938. There has been constant improvement in equipment and personnel, and the safety record is very high. By 1948 improvements were under way to prepare landing facilities for the international lines. The Division of Air Transportation (DTA) at present operates 18 planes and joins international traffic with its flights to Brazzaville and Ponta Negra in the French Congo and to Leopoldville in the Belgian Congo. Commercial aviation has been furthered considerably by the Aero-Clube de Angola, which provides a training school for pilots and for commercial, postal, and health service aviation. Of especial interest is the use of planes by the Angolan Health Service, which maintains an ambulance plane as a part of its regular equipment. In a country as large as Angola, medical air service will do much to overcome the primitive conditions that are still the rule. Although natural conditions are healthful, native health is poor, for despite government and mission efforts health work in rural areas has not made great progress.

The climate of Angola is, in general, salubrious. Even though by latitude and general climate the colony is both tropical and subtropical, certain areas may be counted as temperate. Angola and Brazil have frequently been compared climatologically, but this is not accurate, for the Benguela Current so tempers the Angolan coast that certain otherwise poorly located coastal cities become proper sites for the development of European populations. Vast areas of the interior have a sunny but cool and bracing climate, more disease-free than that of Europe. From northern Cabinda down to parallel 12° South, the climate is equatorial; from the twelth parallel to the extreme southern part of the colony, the climate is tropical. Throughout the entire length of Angola the coastal lands enjoy a steady climate, although the relative humidity is high. The interior areas do not have this regularity, and there may be wide variations in temperatures. In most cities of the interior, however, the climate is temperate-dry, although in a few it may be classed as tropical-moderate. Detailed study of the capital and of the district capitals reveals that temperatures in Portugal are higher in summer than are those in Luanda and Cabinda. Indeed, travelers in Angola report that the chief discomfort arises from the cold, and measures must be taken against the rapid temperature fall at night. Absolute minima of temperatures come in July and August and maxima in December and February. Average temperatures are 63.1° F-79.3° F, with the average maxima ranging between 71.2° F and 86.7° F. It must constantly be borne in mind that altitude and ocean currents, as well as wind currents, make habitable large portions of the country which, considered strictly from the viewpoint of location, would appear unsuitable for settlement by white Europeans.

There are two distinct seasons in Angola: the wet, from October to April; and the dry, from May to September. As the wet season is interrupted for a short period, the rains are divided into the "little rains" (November and December) and the "big rains" (March and April). In general, rainfall increases from the coast to the interior and from south to north. Annual precipitation in the Planalto is 40–60 inches, except in the south, where rainfall

is rare. The rains seldom occur after 1300 hours and are generally preceded by thunder and accompanied by strong wind. In certain parts of the Planalto, for example, Nova Lisboa, rain may fall at any moment. Because of stream changes the extreme southeastern corner of Angola is becoming increasingly desert, and heroic measures have been suggested in order to reclaim the section known as the Kalahari Desert. This area was not desert even seventy years ago, and it has been suggested that the Cunene and Cuando rivers be dammed in order to bring their waters back to Ovamboland and N'Gami. This would again fill the Kalahari lakes, which formerly covered an area of 50,000 square miles and would bring back to productivity the good grazing and farm lands of that region.

A study of the climate and of the six generations of Boers in Humpata, as well as of the settlers who are descendants of colonists from Maderia and the Metropole, proves the feasibility of colonization in most of the Planalto and along the southern coast. The Plateau of Humpata has a dry, temperate climate; fogs occur rarely, and then only along the larger streams; cyclones are unknown; tornadoes are uncommon and unimportant; and there is abundant drinking water. These southern plateaus are the best lands for acclimatization and propagation of the white race; those of the north might better be used for commercial colonies and agriculture. Population possibilities for permanent settlement in the lands most suitable for white colonization have been calculated at 4,298,000 as conditions stand today. These calculations are made on a basis of 40 acres per family of 4 persons plus 4 Negroes—that is, 5 acres per person. This figure indicates the maximum number that could live entirely from the soil without any imports and without rotation of residence.

The soil of Angola does not show great chemical variation from that of Portugal except for lime, which is quite rare. Although the loose, sandy soil does not look encouraging, bracken springs up in a week or two on fresh cuts, and a hole dug in the ground will have water in it the next day. None of the soil of Benguela is extremely fertile, but most of that of the Bailundo and Caconda districts has a good reserve of plant food and could be improved by proper cultivation and the addition of lime. Many soils of the Planalto are derived from granite, which produces a light, easily worked soil, often rich in potash. Others in this region are derived from sandstone—a granite debris. To the north and northwest of Bailundo are soils derived from gneiss, rich in lime and its basic minerals. To the northeast of Bailundo are the fertile red soils derived from igneous basic rock. The northern slope of the Benguela Plateau has a deep soil with rocks lying 6–10 feet beneath the surface. The depth of the soil and the gentle slope of the land make it ideal for tractor tillage. Other soils in Benguela are not so good, as they vary from the deep soil mentioned to thin, patchy soil with rock outcrops. An analysis of fifteen soils from the Benguela and Caconda highlands shows limestone deficiency, but phosphoric anhydride, potash, nitrogen, and a high proportion of organic matter are present. The soil of the uplands is suitable for cereals and vegetables, especially tubers. This information, based on data from Gregory and Taruffi, should encourage European settlers prepared to take up as much as 12,000 acres and to use mechanical methods of farming. Small isolated land-holding has not proved practical.

Because of the great size, different geological formations, and diverse climatological areas of Angola, its flora is rich and varied. The colony may be divided into four phytogeographic zones: Lowlands (coastal); Rich (forest); Highlands (grasslands); Interior (rubber). It is a phenomenon of tropical West Africa that vegetation is more luxuriant north of the equator than south. Southern Angola is in a desert area, although the region of Dakar, at an equal distance from the equator, has vigorous vegetation. The coastal belt of Angola has mainly scrub growth. In the northern part of the Planalto light, open forest is interspersed with savanna, and in the south bush and grass steppes predominate. Vegetation along the rivers is the same in all regions. The most complete studies of the flora of Angola are those made by Welwitsch almost one hundred years ago. Later studies by Baum, Passarge, Steiner, Marquardson, and Almeida are also valuable. Of the more than 400 plants described by Baum, 64 are common to America and 12 to Europe and Australia. In this article, no attempt can be made to present a list of the plants found in Angolan territory nor to discuss definite geographic limits for the ones mentioned.

In the past, European settlers have not taken full advantage of the native flora and have tended to favor wheat, peas, flax, and hemp to the exclusion of the hardier indigenous products—except maize. They have lacked the initiative necessary to grow fruits and vegetables, although conditions are favorable to both. Citrus fruits grown in Angola are of extremely fine flavor. The principal agricultural products today are maize, sugar cane, sweet potatoes, manioc, beans, coffee, and cotton.

Maize and beans are complementary crops, and an increase in the one causes an immediate decrease in the other. Other important products are oil and coconut palms, tobacco, rubber, cocoa, sesame seed, castor seed, wheat, rice, rye, oats, barley, buckwheat, and peanuts.

Manioc (*Manihot utilissima*), although originally imported from South America, is today the principal food of a large number of the natives, and whites have also used it successfully, although it has a very high percentage of free starch. The peanut (*Archis hypogaea*), called *ginguba* by the natives, is used mashed to a paste with chilis from a half-wild bush. Europeans use the peanut for food and oil. The earthpea (*Voandzeia subterranea*), similar to the peanut, is also grown. Other legumes are kidney bean (*Phaseolus vulgaris*), small kidney bean (*P. lunatus*), common bean (*Vicia faba*), pea bean (*Piscum sativum*), chick pea (*Cicer arietinum*), cowpea, or *Catjang* (*Vigna catjang*), *lablab* (*Dolichos lablab*), and Indian dhal (*Cajanus indicus*). Bean fields in Angola yield as much as 40–50 bushels per acre.

Potatoes also have a high yield. The ordinary white potato produces an average of 200 bushels per acre, and sweet potatoes average nearly 400 bushels per acre on good land.

Most cereals do well, especially on the plateaus. Maize is the most important of the cereals, and the white (*quinundo*) or early yellow (*cateta*) will average 22–27 bushels per acre. Wheat can be grown twice a year and generally yields 18–22 bushels, although the harvest has run as high as 40 bushels on the Cuito Farm. Other cereals are grown in various areas. Rice flourishes in the north; Kaffir corn (*Andropogon sorghum vulgaris*) is found extensively in several regions; millet of the spiked or bulrush variety (*Pennisetum typhoideum*) produces grain spikes 12 inches long; barley and oats are not at present important crops.

Cotton has been grown for years in the lowlands, but an experiment at Cubal, 3,000 feet high and 125 miles from the sea, produced favorable results. Caravomica, Egyptian Upland, and Peruvian were tried. The Peruvian was found to be the best adapted; it produced 400 pounds per acre. The first year, plants averaged 200 bolls and stood 6 feet high.

Sisal (*Agave sisalana, Sansevieria longiflora,* and *S. angolensis*) is a very important agricultural product of Angola and continues in demand despite customer complaints. The fiber is hard and not first-class, and the continued demand for the 1950 crop can be attributed only to the supply problem that faces the world today.

Farm and plantation fruits may be divided into those that have been introduced from Europe and those that are indigenous. Among the former are oranges, limes (now growing wild), grapefruit, apples, pears, figs, plums, mulberries, grapes, and mangoes; among the indigenous are pawpaw (*Carica papaya*), which is commonly cultivated and whose leaves will turn tough meat tender, banana, custard apple, or sweetsop (*Anona cherimolia*), soursop (*A. muricata*), pineapple, and guava.

Coffee is an important export crop. Throughout 1949 and the early months of 1950 the fantastic rise in coffee prices was reflected in the Angolan market. Prices more than doubled in three months. In addition, there was a good harvest—42,000 metric tons—and the colony was able to export all of it and 5,000 tons from the reserve stocks. There are native and imported species; both are now cultivated and both grow wild. Many plantations are merely wild plants that are pruned and tended. *Coffee arabica, C. liberica, C. hypoglauca, C. melanocarpa,* and *C. jasminoides* all grow well, but the last two are not profitable.

Rubber is indigenous, and production is good, although many plants have been destroyed by the natives' wasteful methods of gathering. Rubber went from Angola to Germany during World War II. Plantation cultivation could develop a profitable industry. The following would be suitable: *Landophia Owariensis, L. Florida* or *Kirkii, L. crassifolia, L. parvifolia, L. Henriquesiana, Carpodinus chylorrhiza, C. gracilis, Raphionacme utilis, Funtumia elastica, Manihot glaziovii, Hevea brasiliensis, Castilloa elastica,* and *Ficus elastica.*

Cocoa (*Theobroma cacao*) flourishes; tobacco is grown near most of the native villages and has become an important crop; palm nuts (*Cocoa nucifera* and *Elaeis Guineensis*) are generally collected from wild trees, although there are a few plantations. Other products from wild trees are gums (*Acacia Kirkii, Canarium edule, C. schweinfurtii, C. almeidina, Euphorbia rhipsaloides, Fockea multiflora*); dye and tanning products (*Pterocarpus erinaceus, Copaifera coleosperma, Berlinia Baumii, Pelargonium benguellense, Eriospermum flexuosum, Copaifera mopane*); and gum copal.

Certain indigenous trees are now being grown experimentally in plantations for drugs, among them cola (*Cola acuminata*) and quinine (*Chinchona* sp.)

In the past, domestic animals in Angola have been limited in number and subordinate in importance to wildlife, but livestock-raising has great possibilities. Goats, sheep, hogs, mules, and even

horses are found in restricted areas and numbers, but cattle are common throughout the colony. The best area for them, however, is the Planalto. Angolan cattle are chiefly of three breeds—the Quillenges, Seles, and Yenges. They are small (300–400 lbs.), but well shaped, and improvement of the stock is in progress. Hereford bulls have been imported. Vaccination against an infectious peripneumonia (*caonha*) and against *sarna,* a skin disease, has been effective. In 1948 and 1949 the government undertook to survey the underground water supply in the southern plateau, and to extend the Massamedes Railway. This will open an enormous territory hitherto closed because of seasonal water-supply failures and lack of transportation. Various marketing commitments have been made with European powers. It has been estimated that enough meat can be grown and processed in Angola to meet a large part of the lack now felt in Europe.

Sheep-raising has been encouraged. Rambouillet, Portuguese, and French merinos have been imported for breeding wool sheep, Persian blackheads for mutton sheep. Horses suffer from the tsetse fly and from horse-sickness. Those in the colony have generally been owned by the Boers in the highlands. Swine appear immune to most of the animal diseases, although they were decimated by the pest in the plains of Benguela in 1942. Despite this there should be a big future for hog-raising in Angola provided a measure of sanitation can be observed. At present domestic pork is to be avoided because of the unsanitary drainage and sewage systems. Domestic fowl thrive, although the native breed is small and skinny; however, improvement of the breeds and of marketing facilities would make this a major industry with a good European outlet.

Angolan fauna is representative of African fauna in general, but any attempt to establish a game map would be impossible, as the rapidly diminishing game population would cause such data to change constantly. Wildlife in Angola is of immense economic value, and more rigid game laws should be enacted. The Boer colonists have been especially harmful hunters.

Birds present an even greater problem of classification than do the animals. Bocage has described 700 species found in the colony: 332 Passeres, 137 Picariae, 89 Grallae, 59 Accipitae, 20 Gallinae, 12 Columbae, 15 Gaviae, and 14 Anseres.

Insect control in Angola will bring about great general improvement, for insects play an important role, and unfortunately their influence is usually evil. There are some natural controls, however, and even moderate effort would solve the problem. Bees bring much wealth to the colony and could, if honey- and wax-gathering methods were improved, become an even greater source of income. Ants are ubiquitous and vary from small food ants to the white ants—in reality a termite. The most feared is the driver, or warrior, ant, whose bite is extremely painful. These insects move in a column and destroy all before them. As they travel at night, a camp is often attacked and the only recourse is flight.

Flies, wasps, and butterflies are numerous, although there are few butterflies not also found in other sections of the African coast. The common housefly abounds in the coastal towns and throughout the colony. There is also a biting fly (*Stemoxys*), which resembles the common housefly, and the suicide fly—a small bee—which neither bites nor stings, but its persistent efforts to crawl into nose, eyes, ears, and mouth make it one of the most exasperating of all insects. Wasps and dragonflies do not bother man and are valuable insect killers. The mantis also lives on insect pests and is especially fond of the housefly.

Mosquitos are the most widespread disease-producing insects found in Angola. The malaria-carrying *Anopheles,* found mostly below 4,225 feet, can largely be controlled merely by channeling the watercourses. The *Aïdes,* which carries the yellow-fever germ, as well as *Culex,* suspected vector of dengue fever and *Filaria elephantiasis,* are found in almost all localities. These also may be controlled by channeling the watercourses and by use of insecticides.

At least two varieties of the tsetse are disease carriers, and the entire *Glossina* genus is suspect. *Glossina palpalis,* carrier of the trypanosome that causes sleeping sickness in human beings, and *G. morsitans,* carrier of the fly disease to animals, are both found in Angola. The former lives along the streams and feeds largely on crocodiles; the latter feeds on animals in the dry forest regions. Fortunately the tsetse fly is confined to northern Angola, and there are millions of acres of the central highlands that are entirely free of it. Eradication of the tsetse is an international problem, for the entire area which bounds Angola to the north—the French and Belgian Congos—is infested. To the south, tsetse infestation is almost unknown. *Morsitans* is found near Caconda, *palpalis* along the Cubal and Catumbella rivers, perhaps even between Benguela and Mossamedes, but many were destroyed by the rinderpest a few years ago.

There are many varieties of ticks in Angola, and most wild animals are infested. Certain of

these ticks are vectors of diseases attacking domestic animals, as, for example, *Rhiphicephalus appendiculatus,* which carries the red water fever of cattle, and *Haemaphyllis leachi,* carrier of the biliary fever of dogs. The ordinary tick will cause only discomfort to man, but *Ornithodonus moubata* carries a spirillum which is the cause of relapsing fever. In the lowlands of Angola is found the Congo floor maggot fly (*Auchmeromyia lusteola*); the tumbler fly (*Cordylobia anthropophaga*), which resembles *A. lusteola* in appearance; and the chigoe, or burrowing flea (*Scarcophylla penetrans*). There are two varieties of scorpion, a yellow and a black. The black is the more deadly, and its bite will cause complete, though temporary, paralysis in an adult, and in children even death. There are few centipedes, but harmless millipedes 6–8 inches long are common.

Angolan snakes number more than 100 varieties, but less than one half are poisonous. The most dangerous are the mamba and spitter cobra. The former (*Dentraspis neglectus*) can kill a man in a few minutes. The spitter (*Naia nigricollis*) is able to eject its venom some distance and to blind the enemy.

Angola is rich in minerals, many of them strategic, and they are readily accessible. Great copper deposits lie in an area some 200 miles long by 10 miles wide in the Catanga, and there are other copper deposits in Quibela and Cuio. Malachite is found near Bembe and in the interior of the Congo District. There are many diamonds, most of them of gem quality. These are found in Lunda District near the Belgian Congo border; in the east at the confluence of the Cuido and Cuango rivers; and in the south-central region along the Cuanza and Cubango rivers. To date they have played a substantial role in the country's economic development and will continue in increasing importance. Gold is also an abundant mineral resource and is located in many parts of the colony: in Golungo Alto and Bailundo; in auriferous sands in the Mossamedes region; in streams in the Benguela section; and in the alluvial land of Cabinda Enclave.

Less developed, but nonetheless important potentially, is the iron found throughout the colony, especially in Mombassa and Bailundo. Smelters were once set up at Oeiras, but were later abandoned. It is estimated that at present 2 million tons of ore are readily available. There are also considerable quantities of coal of a soft bituminous type, impregnated with asphalt, at Calucala, Quilungo, Dondo, and on the Benguela Plateau. The volatile material content is high. Libolite, an inferior coal of little value, also exists in an area of some 8,000 acres in Luanda. There are large asphalt deposits at Libungo. Petroleum is found in the form of bitumen in Dande, Kitatua, Kabangana, and Quizão in the Congo region. Prospecting continues, as oil is believed to exist in good quantities.

Other mineral deposits are salt, both rock and marine deposit; sulfur in the hills of Dombe Grande, Cabo Lede (Cuanza Sul), and Cuio; gypsum along the coast—especially in Benguela; gypsum and sulfur at Morro das Langostas and in Benguela; manganese of good quality at Lucala, Lombije River, and Zenza; mica in the Ambriz and Dande regions; and lead, guano, marble, and limestone.

Among the mineral resources must also be counted the various hot springs: N'Gelo at Tacota Mountain, 40 miles from Nova Redondo; near Damba in the river bed of the Sanza River, 112 miles east of Lobito; in Moxico on the banks of the Zambezi near the Matunda Makhesi rapids. Water in a series of springs in Ochilessa on the banks of the Cuimo River reaches a temperature of 113.9° F.

Good ports and shipping facilities are vital to Angola because of her increasing manufactures, as well as because of her minerals and agricultural products. Already some advance has been made in industry despite the general policy of the Portuguese government to develop nothing in the overseas empire that may compete with the Metropolitan area. Angola has a textile mill, shoe factories, numerous fish-processing plants; a flour mill, with an annual capacity of 12,000 tons of wheat; sisal and palm-oil processing plants; and soap, tobacco, match, and alcohol industries. *Alcoolina,* a mixture of alcohol and gasoline used as motor fuel, is produced from the great quantities of by-products from the numerous sugar refineries. Refrigerating plants have been established at Nova Lisboa and Lobito in order to export meat, fowl, and fruit to the other colonies and to Europe, and similar plants are designed for Mossamedes and Luanda. Quick-frozen and refrigerated meats, fruits, and vegetables are the answer to the marketing question and are very important to the economic development of Angola. Fortunately she is rich in water power, and hydroelectric plants can furnish more than enough electricity for her growing economy. Several of the less powerful falls have already been utilized, but the Coemba Falls in the Coemba-Moxico River, with a minimum usable power potential of 4,160

hp, and other great falls of the Intermediate Zone are still untouched.

The progress that has been shown in the industrialization of Angola is a factor to be considered in the colonization of the country, for increased production is indicative of the incorporation of more native labor in modern industry, and consequently of improvement in the potential of collective labor, as well as of a higher standard of living. The native represents the greatest asset of the colony, and, despite the present policy of keeping him out of industry, he will eventually occupy a big place there, for lack of manpower is the chief drawback to Angolan progress today.

The first official census of the colony of Angola, taken in 1940, registered a population of nearly 3,800,000, divided into "civilized" and "uncivilized" groups. Among the former are classed "all those individuals who by their customs, morality, education, profession, and level of life, approach through all these attributes or the majority of them, the average Europeans in their own social groups." The civilized group consisted of 44,083 whites, 23,244 Métis, 24,221 Negroes, and 63 others. The uncivilized group included 2,791 Métis and 3,641,608 Negroes. The word Negro is here used to designate the entire indigenous population, although the term is not strictly applicable, for Khoisan as well as Negro tribes are included. Of the different ethnographic, linguistic, and anthropological groups on the African continent only these two are of interest to the Angolan territory. The Negro includes the pre-Bantus (Vatuas) and the Bantus; the Khoisan includes the Hottentots and the Bushmen. The Bantus belong to the linguistic and cultural unit of the race of the same name. According to general supposition, the Khoisan are the primitive race and the Bantus are invaders from the north. The Khoisan group is greatly reduced and is of little significance in the economy or the ethnography of the colony. Only in the south (Huila and Bié-Sul) have traces of the Khoisan people been found. There are none in the center and north, and very few pure Hottentot families are found anywhere, although a few were brought in by the Boers and left in Humpata and Chitado. In lower Cunene there are Hottentot families crossed with Bushmen who still speak the Hottentot language, although today they have largely taken over the Bantu dialect.

In the south, traces of pre-Bantu Negroes also are found. They belong to the group called Vatua ("wandering") and are not Bantus. The present native population is divided as follows:

BANTU GROUP
(Subgroups)

Kikongo	Lunyaneka (Vanhanecas)
Kimbundu	Lunkhumbi
Lunda-Kioko	Xikuanyama (Ambos or Vaambo)
Mbundu	Xindonga
Ngangela (Ganauelos)	Tyihero (Va-herero)

(These subgroups are again divided into many tribes, but this further division is not necessary, as the ten main language groups correspond to these subgroups.)

KHOISAN GROUP

Hottentots (Bacancalas)
Ovakede (Bacassequeras)
Vakwankala (Camussequelas)
Vakasekele (Mucassequeras)

VATUA GROUP
(Not Bantu)

Vakuisi (Bacuissos)
Vakuandu (Bacuandos or Mucuandos)
Vakuepe

Civilized Negroes form only a very small percentage of the total native population—24,221 out of 3,665,829. A few have been trained as nurses and dispensers, and as teachers in both government and mission schools, but the majority are trained for agricultural work. Primary instruction is given in a separate branch for natives and has a professional character; Portuguese and native languages, arts, trades, and agriculture are taught. The curricula of the professional schools include the rudiments of reading and writing, and the elementary principles of trades, as well as the rudiments of practical agriculture. The school program is designed to keep the native on the land and out of the laboring class, thus preventing competition with European laborers. Despite this program, however, more and more native labor is entering the factories. This has caused a remarkable increase in production, and in the belief of many it is advantageous, as it raises the standard of living throughout the colony.

Native education has recently been reoriented in line with the native's type of intelligence, which has been characterized as prelogical, or capable of development into logical thinking. The general objectives of the new educational system are:

1. To develop rural workers and overseers for agriculture and animal husbandry work among the natives.
2. To give elementary instruction in personal hygiene and in living conditions.
3. To teach the Portuguese language, written and spoken, in order to intensify the nationalization of the native.

The language requirement for Angolan schools has been a point of dispute between the Portuguese government and foreign missions, especially the English-speaking ones. It is, however, of the

utmost importance in a land of diversified native dialects, where there is not even a lingua franca such as the "Kitchen Kaffir" of South Zambezi, or the Ki-Swahili of east and central Africa. Although in general the native tongue is Bantu, the speech varies greatly in different sections.

Any discussion of the Angolan native must be centered around the characteristics of the uncivilized Bantu group that comprises the majority of the population. All work in the tropical sections must be done by natives, and the settler will in many instances be entirely dependent on native help, for there are areas where the white man cannot till his own fields.

The native character has been to a great extent molded by the climate. Where life is so easily maintained at a minimum of effort, the natives are lazy. They seize every opportunity for merrymaking and turn it into an excuse for drinking. Most of them smoke; tobacco is found near many villages, and wild hemp (*Cannabis sativa*), called *diamba,* is smoked in a hookah. This latter is a social and moral problem recognized even by the natives themselves. Attempts by the elders to control the practice have sometimes led to tribal revolts.

Settlers will find the Negro normally honest as regards property, and faithful to his acknowledged master, but totally lacking in appreciation of the sufferings of others and in a sense of truthfulness. His lie is artless, but not purposeless—he strives either to please or to attain his own ends. He is cheerful, but without fortitude or judgment, and these factors must be considered in his work and in his education. He is not lacking in worth-while qualities, and it is thought that they need only be developed and given proper direction. He is kindly and loyal, despite his tendency to abandon a master who can no longer command. This tendency, it is claimed, comes from a centuries-old tradition of obedience through fear and could be overcome by education. The natives are, in general, tractable, and there is little police difficulty. They have great respect for their own traditions and customs, although in some areas the destruction of the power of the chiefs and the ravages of smallpox some thirty years ago have greatly altered customs and character. The kings of the Congo still retain their titles, and much ceremony is observed between them and their visitors, but neither this title nor those of marques and count granted by the Portuguese 300 years ago have much importance today. The Portuguese policy in Angola is to destroy native power and authority, and to do away with all except purely nominal native rulers. This program has diminished the numbers of native uprisings.

The native form of government is communal and patriarchal; the small chief, or *Sova,* rules over a group of villages or over even a single village that may consist of a single family. He is assisted by a council, which includes, in addition to a prime minister, minister of war, and secretary, the chiefs of the villages over which he rules. At the death of the *Sova* the council governs until it has chosen a successor—generally the eldest son of the deceased's eldest sister, as it is believed to be more certain that the sister of the *Sova* be the daughter of the *Sova's* mother than that the *Sova's* child be his own. More probably, however, it is the influence of the ancient custom of mother-right rather than fear of female frailty that determines this order. Marital fidelity is neither expected nor considered desirable, and a rich lover is often encouraged for the fines he pays.

Civilization has had little effect on religion. Any traces of Christianity that may have reached Angola in the fourteenth century have been completely obscured by spirit-worship, which in turn has been altered by Western civilization. Mohammedanism is spreading throughout West Africa, but has influenced Angola very little. Totemism in an obscure form exists, and taboos are recognized. The self-inflicted penances that often accompany taboos bear a close resemblance to penances imposed by Christians.

Certain societies with a more or less religious character may be formed, but native societies usually have political significance; such were the "Leopard" and the "Crocodile," broken up in 1912. Another was formed later among the young Lunda men as a protest against a tribal interdiction of hemp-smoking. It was a political and radical union directed against the more conservative elders.

Fetishism is the use of the *feitiço,* or charm against evil spirits. The Angolan native pays little heed to a vague though beneficent deity, but propitiates the evil spirits at every turn with charms and incantations. Fetishism may on occasion be of aid to the European, for it is "fetish" for any native chief to injure or rob a person whose hospitality he has accepted. Settlers or travelers in hostile sections can use this fact to advantage. It is also "fetish" for a native to break a white man's property, and use can be made of this, in case of danger, by letting a chief break an already cracked article.

Living standards of Angolan natives are extremely low, especially in the case of the Khoisan people, who make no provision for the future. The Bantus, on the contrary, never leave meat to spoil,

and their women farm the land. Maize or manioc is the chief article of diet. In addition, millet, yams, peanuts, pumpkins, and such fruits as bananas and pawpaws are eaten. Meat in general is eaten except under individual taboos, but beef and milk are rarely used. Butter is used only as an ointment. In feeding the natives transition from manioc to mealies (or the reverse) must be gradual, as the native cannot change suddenly from one to the other without distress and illness. Portuguese law requires that natives be given beans, salt, onions, and meat at least once a week, but as there is little control exercised the general practice is to give little except manioc. Porters on the march live on about two pounds of manioc flour (*fuba*) porridge per day.

Native housing is primitive, and there are few permanent villages. The huts are only rough shelters of bush and grass, generally round, topped by a conical, sloping roof, and some of them are nothing but sloping boughs covered with leaves or grass. In the Congo Province the huts are square and better built. Houses of the river island-dwellers are raised on piles. Among the nomadic Ba-Cuissos (Bushmen), a hut is simply a circle of stones.

Clothing among the natives is a most economical item, but there are no completely naked tribes. The women wear a length of cloth wound about the waist as a sort of skirt, or often merely two strips of bark hung on a thread around the waist. The breast is usually not covered, although at times the skirt may be raised to the armpits. Tribes of the uplands, like the Bailundos and Biés, wear only a little more clothing, but what there is of it is warmer, as it usually consists of skins.

Europeans who come from nearest the equator have been considered as best able to endure African conditions. It is true that the most adaptable settlers have been the French, Italians, Spanish, and Portuguese, but the Boers are at least one exception to this. The first distinct foreign element entered Angola in 1880 when several hundred Boers trekked there from English territory. Well received, they lived in Angola for many years, although they were never part of it. Linguistic and religious differences prevented complete amalgamation, and in 1927 the Boers withdrew to Damaralandia. However, from the economic and health viewpoints the Boer colonists proved the suitability of northern Europeans as settlers in Angola. One group of 929 who settled in Angola in 1895–98 had a mortality rate of only 8.1/1,000 during a period of sixteen years. This experience leads one to the belief that a careful study would show that not the area of origin but rather the motive for emigration, plus physical fitness and temperamental aptitude for adjustment to new situations, has been the real factor in determining successful settlement.

For administrative purposes the Colony of Angola is divided into five provinces, subdivided into fourteen districts. The head of the government is the governor-general, appointed by the Council of Ministers (Lisbon) on nomination by the Minister for the Colonies. The governor-general is aided by a government council, whose function it is to control his legislative acts. However, as the council has no legislative power and as the members, except for a small elected minority, are appointed by the governor-general, any opposition, even His Excellency's most loyal, is rather effectively stifled.

Angola, together with S. Tome and Principe, forms one of the Portuguese Overseas Judicial Divisions and belongs to the Luanda Court of Appeals. The Administrative Tribunal of the country acts as guardian of municipal interests and as a court of appeals for taxpayers against tax levies.

Banking facilities are provided by the Banco de Angola, a private bank of issue that also acts as a commercial bank. The colony is further served by a branch of the Banco do Comercio e do Ultramar, and by a land-credit bank, the Junta Central do Credito Agricola. The angolar is freely convertible in Portugal with the escudo and through this —with certain formalities—into any other currency. Every effort is made to integrate the economy of the colony with that of the Metropole. The present government of Portugal considers that the territory in Europe and the territory overseas constitute a single state with interdependent and mutual interests. The *Acto Colonial* recognizes colonization of the overseas empire as a duty, and the program for study of resources and planned colonization is predicated on this idea.

Historically, the Portuguese government has favored settlement in Angola and has subsidized settlers. Especial note must be made of this, as certain sources maintain that the Portuguese government is inimical. This is not true at present, nor has it been in the past. Plans for state subsidy were made under Francisco Inocencio de Sousa Coutinho as early as 1764–72, and the policy has not been changed. Throughout the nineteenth century settlements were made with state aid, and a definite program was developed for the country. In 1949 and 1950, in accordance with this program, special concessions were granted on imports of agricultural machinery and other items in order to

encourage more labor to come into the country.

There have been clashes between the Portuguese and other powers. These are inevitable when a land as rich as Angola appears to be there for the taking. Various powers have made more or less open, but always continuous, efforts to absorb Angola into their economic and political spheres. One of the main lines of attack is to pretend that the colony is valueless; another, and this is supported by Protestant foreign missions, is to pretend that the Portuguese government does not want settlers and suppresses the native. This is not true, but Angola is a Portuguese land with centuries of Portuguese tradition behind it, and it is entitled to maintain both its government and its traditions.

The Colony of Angola was discovered about 1482 by the Portuguese explorer Diogo Cao, and immediately thereafter his compatriots began the colonization of the interior of Africa. By 1530 a flourishing colony had developed, and a bishopric was established; traces of the sumptuous buildings still exist. From 1641 to 1648 Angola was under Dutch rule, because of Spanish domination of the Iberian Peninsula and consequent political inability of Portugal to administer her colonies. Later, because of the importance of trade with the East Indies and, subsequently, with Brazil, Angola remained of relatively little importance to the Metropole except for the traffic in slaves. In the early nineteenth century abolition of the slave trade and increasing emigration to Brazil reduced the already weak trade and development of Angola. Only since the independence of Brazil, and more especially in the past sixty years, has any real development been achieved. This has been aided in part by the requirements of the international mandates after World War I. The need for colonial products and military bases in both world wars also gave impetus to her development. The chief factors responsible for her recent growth, however, are the technological advances of the past few decades. These have been peculiarly well suited to Angolan needs and in the past five years the colony has made real progress. In a world disturbed by political strife, economic and social unrest, Angola is a peaceful land rich in natural resources and potential labor, prosperous and confident as she faces into a bright future.

How, indeed, can any man, and how more especially can any man of scientific culture, think special results of special political acts can be calculated, when he contemplates the incalculable complexity of the influences under which each individual, and *a fortiori* each society, develops, lives, and decays? The multiplicity of these factors is illustrated even in the material composition of a man's body. Everyone who watches closely the course of things must have observed that at a single meal he may take in bread made from Russian wheat, beef from Scotland, potatoes from the midland counties, sugar from the Mauritius, salt from Cheshire, pepper from Jamaica, curry powder from Spain, as well as various spices and condiments from other places; . . .

And what thus holds of the substances of the body, holds no less of the influences, physical and moral, which modify its actions. You break your tooth with a small pebble among the currants, because the industrial organization in Zante is so imperfect. A derangement of your digestion goes back for its cause to the bungling management in a vineyard on the Rhine several years ago; or to the dishonesty of the merchants at Cette, where imitation wines are produced. Because there happened a squabble between a consul and a king in Abyssinia, an increased income tax obliges you to abridge your autumn holiday; or, because slave-owners in North America try to extend the "peculiar institution," . . . there results here a party dissension which perhaps entails on you loss of friends. If from these remote causes you turn to causes at home, you find that your doings are controlled by a plexus of influences too involved to be traced beyond their first meshes. Your hours of business are predetermined by the general habits of the community, which have been slowly established no one knows how. Your meals have to be taken at intervals which do not suit your health; but under existing social arrangements you must submit. Such intercourse with friends as you can get is at hours and under regulations which everybody adopts, but for which nobody is responsible; and you have to yield to a ceremonial which substitutes trouble for pleasure. Your opinions, political and religious, are ready-moulded for you; and, unless your individuality is very decided, your social surroundings will prove too strong for it. Nay, even such an insignificant event as the coming of age of grouse affects your goings and comings throughout life. For has not the dissolution of Parliament direct reference to the 12th of August? and does not the dissolution end the London season and does not the London season determine the times of business and relaxation, and so affect the making of arrangements throughout the year? If from coexisting influences we turn to influences that have been working through past time, the same general truth becomes still more conspicuous. Ask how it happens that men in England do no work every seventh day, and you have to seek through thousands of past years to find the initial cause. Ask why in England, and still more in Scotland, there is not only a cessation from work, which the creed interdicts, but also a cessation from amusement, which it does not interdict; and for an explanation you must go back to successive waves of ascetic fanaticism in generations long dead. And what thus holds of religious ideas and usages, holds for all others, political and social. Even the industrial activities are often permanently turned out of their normal directions by social states that passed away many years ago.—HERBERT SPENCER. The Study of Sociology. *Pop. Sci. Monthly*, **1**, 1 (1872).

D. H. Lawrence and Science

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THE depth, range, and vitality of a writer in our age can in part be measured by his response to the challenge of the scientific outlook. Escape this influence he cannot, no matter how hard he tries. Whether he negates or affirms, accepts or rejects, he is compelled, by the prevailing climate of opinion, to come to grips with it. There is scarcely a writer of note in the twentieth century who has not been profoundly affected by the discoveries and implications of science. Hemingway, Dos Passos, Dreiser, Farrell, Aldous Huxley, Robinson Jeffers, Auden, William Faulkner, even Virginia Woolf and D. H. Lawrence, have revealed in their work the degree to which they have been enlightened or alienated by the scientific synthesis. Their vision of the world has been radically transformed, so that they view themselves and others and the nature of their experiences through different perspectives. The theory of relativity, quantum mechanics, determinism, indeterminism, Freudianism, anthropology, general semantics, dynamic logic, instrumentalism, the logic of physics, Gestalt psychology, behaviorism, endocrinology, genetics, eugenics—it is difficult to determine precisely the extent to which science informs the literary mind. Just as Newton influenced poets by his experiments on the nature of light, so modern writers have been influenced in a rich diversity of ways by the various scientific disciplines.

To be sure, this is not unprecedented. The scientific revolution (What a traumatic shock it administered to the organism of modern man!) has its ideological antecedents in the latter half of the nineteenth century, when the creative mind sought to refute or to reconcile itself to the newly formulated doctrine of biological evolution. But the metaphysical laments of Tennyson, the humanistic plaints of Matthew Arnold, the stouthearted optimism of Browning, Whitman's lusty hurrahs for science, these strike a qualitatively different note from that sounded by our contemporary writers. The quarrel is no longer theological but secular. The issue being fought out is not over the nature of God but the nature of man and his destiny on earth. A whole century intervenes between Tennyson's triumphant affirmation of immortality in *In Memoriam,* his slow and laborious mastery of the doubts that intruded so persistently, and the cosmic pessimism of Robinson Jeffers, the earth-rooted and man-centered humanism of Erich Fromm (in *Man for Himself*), or the existential despair and alienation of Sartre. Though the slogans violently shouted are different, the battle is essentially the same.

The character of the conflict can best be illustrated by studying not those determinists and naturalists who accept the scientific method but those who are up in arms against what they call the tyranny of science. If we look into the reasons for their repudiation of science, we shall discover why they feel the threat so keenly. What, then, are the damaging charges that some of the crusading literati level against science? The one who warred most bitterly and most brilliantly against the deadening effects of the philosophy of science and the scientific method was D. H. Lawrence, who is important not only for what he wrote, the campaign he waged with such inspired vigor, but also for the disciples he gained, the movement he helped to launch, a movement which, under the sign of the phoenix, is still going strong years after his death.

The antiscientific animus gathered ideological strength from a number of sources, both past and present. Without question, what has attracted many intellectuals to the work of Vico are his ideas on history and language, particularly his views on poetry and the early speech of man. Primitive speech, he believed, was crude but concrete, simple but sensuous and passionate, and therefore essentially poetic, free from the vice of abstract thinking. And it was poetry that helped to mold the imagination of primitive man, who was unburdened by any

philosophical preconceptions, rational insights, and scientific explanations. He could hear, see, feel, touch, smell, taste, and his word-poems had to represent sensations and feelings. Indeed, argued Vico, there was at the time no separation between imagination and reason; the whole man was of imagination all compact, and that is how he reacted to experience, that is how he "thought"—*imaginatively*. Poetry, in short, was Nature, not Art.

Vico thus lent powerful ammunition to those modern writers who, like D. H. Lawrence, have been opposed to the "intellectualization" of the creative process. It is obviously to the interest of the artist to isolate a logic of the imagination distinct from the logic of scientific thought. Science abstracts from reality and therefore misses a great deal. It deals in instruments, formulas, measurements, generalized laws. Art indicates that science presents but one aspect of reality; there are others equally important and revealing. Art has for its object the capturing of reality on the wing, its mutable surface, its atmospheric effect, its infinite variety, its innumerably varied perspectives. Through the sensuous forms it creates, art gives an interpretation of reality. Art must therefore be studied as an independent creation. Hence the contention of some philosophical critics that the intuition embodied in a work of art is not only different from but superior to the scientific truth born of empirical rationalism. Science gives us uniformity, art the multiformity, of appearance, the full variety of life. As Ernst Cassirer, however, points out in *An Essay on Man*: "The two views of truth are in contrast with one another, but not in conflict or in contradiction. Since art and science move in entirely different planes they cannot contradict or thwart one another."

D. H. Lawrence decided to go further than that. Apostle of twentieth-century Rousseauism, he revived the conflict between Instinct and Intelligence. It was Rousseauism with a marked difference: the sentimentality excluded, the generalizations about virtue eliminated, the concept of the noble savage reduced to the status of a myth. A new type of Laurentian sentimentality takes its place: the quest for the primitive, the intuitive, the source of solar instinctive energy in man as the fountainhead of all good, of all true godhood. Essentially, however, the antithesis between Nature and Civilization remains, except that it is interpreted in pseudo-Freudian terms. Lawrence praised the great unconscious and set it against the artificial, repressive consciousness that man abjectly worships. By suppressing his desires and instincts, the divine flow of power within, man becomes a divided being.

Fantastic as much of this sounds, Lawrence was actually more sensible in his revolt against the tyranny of science than we commonly suspect. Since he had to combat science, he would go the limit and thus add a greater margin of freedom to his creative individuality. Lawrence not only worshiped Nature but also the remote past, when man's polarity with Nature was spontaneous and organic. Modern man had lost the secret that ancient man possessed, the secret that lay in instinctive communion with sun and moon, plant and animal. So he searched for the traces of this secret in the ancient societies of the Etruscans, the Hindus, the Egyptians, the Aztecs, the American Indians. All these explorations helped to support his intransigent primitivism, which represented a rebellion against civilization, with its deification of the mind and the machine.

The savage was the new savior. But since the savage disappointed him when he had a chance to study him at close range, he turned to anthropology and archaeology for inspiration and supporting material, reading such works as Frazer's *The Golden Bough,* Jane Harrison's *Ancient Art and Ritual,* Tylor's *Primitive Culture,* Jung's *Psychology of the Unconscious.* So thoroughly did he steep himself in this archaic world that he began to love these dead people of Babylon and Nineveh, Ashurbanipal and the Etruscans; he began to take a passionate interest in totemism, fertility rites, myths of resurrection, and the ancient gods, finding a wealth of stimulating material in myths and the religious rites of old. Here were the pure sources of the mindlessness he so much admired, the animistic passion he endeavored to infuse into his poetry. The mysterious East with its theosophy and Yoga practices beckoned to him, and though there was much in it that he found repulsive, it also contained much that was fruitful for creating a "new religion."

Thus Lawrence created and believed in his own myths. Life, as he saw it, is a perpetual miracle, a process of eternal creation, a continual striving for new incarnations, new worlds. It is this process that keeps the world alive. Any scientific hypothesis or discovery that conflicted with this private myth was either rejected out of hand or boldly revised to suit Lawrence's creative purpose. Calling Einstein's theory of relativity the latest craze, he criticized Einstein's mathematical formula:

> It seems to me, also, that the velocity of light through space is the *deus ex machina* in Einstein's physics. Somebody will someday put salt on the tail of light as it travels through space and then its simple velocity will split up into something complex, and the Relativity formula will fall to bits.

But he perceived that the universal law of the old order had broken down, that we can no longer put our faith in a system of mechanical automatism. In fact, Lawrence professed to believe in relativity himself. "I think there is no one absolute principle in the universe. I think everything is relative." With equal conviction, however, he insisted that the individual creature is absolute, a law unto itself.

Without logical connection he went ahead to insist that the dark side of the self must be given full recognition: the passional, sensual, instinctive self. Blood consciousness, he argued, is the creative source of all that is best and most original in us. What man must do if he is to be saved is to sink back into primordial darkness, the elemental consciousness of the blood. Thus we behold how Lawrence deliberately utilized science for his creative myth-making. Like Vico, he declared that modern man is degenerate because he has personalized everything in the universe, whereas the pagan left his paltry little ego out of the picture, establishing real, vital connections with the cosmos. How different is modern man's scientifically sterile vision of the sun from the vision of the primitive! We behold a flaming furnace of gas; the pagan beheld a magnificent throbbing reality, a radiant godhead to be worshiped. The sun and the moon are alive, and both influence our thoughts, our actions. There is an indisseverable bond between man and the cosmos, which we break at our peril.

Inspiring as all this is as poetic myth-making, since it portrays man as visceral as well as cerebral, intuitive as well as intellectual, it falls down badly as a system of philosophy, practically every assertion constituting a flagrant contradiction. Suppose we agree that there is this vital, quivering protoplasmic connection with the cosmos, what then? What action shall we take? Shall we scrap industrialism, declare a moratorium on science, issue anathemas against the development of technology, raze our cities, destroy the atomic energy plant at Oak Ridge, and reinvoke the primal life in the jungle when gods dwelt in each bush and animal and change of skyscape? The presupposition that primitivism is the closest thing to paradise may be an inspiring theme for the poet who wishes to get palpitatingly close to reality in all its immediacy and sensuous beauty, but it is madness as a proposed way of life for modern man. Intuitions must be tested by reason; the instincts must be controlled by the sense of social reality; the communications from the sun, whatever their nature, must be decoded and interpreted, and we have but one universally valid system of interpretation: the scientific. Otherwise we have no way of knowing whether what we are saying is truth or nonsense.

Lawrence protested violently against the excesses of industrialism, the mechanization of life, both of which cut man off from the instinctive satisfactions that spring from the deepest layers of the self; but even his profound mystical passion could not justify his exaltation of irrationality. What is the basis for this curious belief in the blood and the flesh as being wiser than the intellect? Lawrence was, of course, using the intellect perversely to disparage the fruits of reason. How did he *know* what the blood told him? He refuted the theory of evolution by asserting that his solar plexus knew otherwise. That settles it, presumably, once and for all. We come to understand what Lawrence was driving at when we read his diatribes against the imposition of abstractions for vital realities, the triumph of the scientific method. What counts supremely, according to Lawrence, is sensitiveness of feeling, depth, organic responsiveness to the cosmos. There is no depth to our modern consciousness. Lawrence valued "cult-lore," an activity of the senses, more highly than culture, a product of the mind. Though we have accomplished technological miracles and enormously extended our dominion over Nature, he said, we have also lost much that is irreplaceable: the sense-awareness and sense-knowledge of the ancients, arrived at by instinct and intuition, not by reason. Ancient consciousness negated the strait-jacketed categories of instrumental logic.

The solution, therefore, as Lawrence set it forth in his last will and testament, *Apocalypse,* is that men should think in images, images instinct with emotional substance, not images that are rationalized, logically linked, pointed toward a syllogistic conclusion. Such mental consciousness is fatal. Far better to look upon the heart as the seat of consciousness. Far better to rely on the physiology of the spirit, an organic feeling, chthonian awareness. For the pagan consciousness, God penetrates and pervades all matter, is present in water and rock. Thus Lawrence, singlehanded, waged war against the Moloch of the intellect, the asphyxiation of the instinctive life by the poison fumes of reason. Woe to the Great Whore of Babylon that today has brought the winter of death on the world! The destructive serpent has been let loose; the redemptive dragon has been slain and interred. The Logos has now taken over, "the evil-smelling old Logos" from which he fervently prayed to be delivered. Only when knowledge crept in as a corrupting influence did "the conception" arise, a screen between man and his sensual awareness of the cosmos.

What, after all, asked Lawrence, had man gained from the bitter conquests of science? Nothing but

misery and increased frustration. What could science add to the old instinctive knowledge of the four elements: fire, water, earth, and air? Thought is the antithesis of life. Man still thinks with his blood. The thoughts by which we set so much store are vital and resident in the blood. "Maybe all basic thought takes place in the blood around the heart, and is only transferred to the brain." The true symbol, like the true myth, defies all analytic explanation. The mind understands intuitively, and there is an end of it. The emotional soul, the emotional consciousness of man, transcends the limited mental consciousness. The trouble with modern men and women, particularly the scientists, is that they have a mania for knowledge, analysis, understanding.

Lawrence's repudiation of science did not come without a struggle. As a young man he had read the nineteenth-century scientists: Darwin, Huxley, Haeckel, Spencer, John Stuart Mill, and William James. Converted to the new faith, he dropped chapel and became a militant agnostic. But if he ceased to be a Christian, his emotional need for a fully satisfying faith gave him no peace. Unable to feel at home in a cold, calculating skepticism, he was gradually led to reject the science that had brought him to this pass. Although the religion he finally adopted was not one that could be objectively "proved," it is one that is of the highest interest to the student of contemporary letters. For in its rejection of the scientific synthesis, it illustrates the affirmations the literary mind must make in the teeth of all empirical evidence to the contrary.

Because he sincerely believed in himself and his creative mission on earth, D. H. Lawrence played the role of prophet to perfection. His "religious" impulse is not to be mistaken. The artist was the hero who expressed this religious impulse at its noblest. The truly religious artist—a D. H. Lawrence—acts as the mediator between the human and the mysterious power of the Unknown, and thus succeeds in establishing a new, vital relationship with God. And the gospel Lawrence preached through his fiction and poetry is this very faith in the unseen. Science, materialism, and the life of reason: these were the enemies to be attacked. The intellect was the supreme danger, the foe of life. After banishing the intellect, one could live spontaneously from his dark deep centers, reacting to the *élan vital* of the blood. Science, since it ignored these profound intuitive truths, had only a clinical, empirical notion of the mystery of the body creative and the blood prophetic. The scientists had to be whipped out of the temple, as were the moneylenders by Christ, and Lawrence used scorpion whips of prose, burning with rage and revelation, to accomplish this task of purification. His early reading of science had shown him where science was vulnerable, and he vigorously attacked its mechanical laws, its theories of evolution, its psychoanalytical jargon.

In *Psychoanalysis and the Unconscious* he took Freud roundly to task for his enslavement to mechanical science, his blindness to the miracle of the psyche, the inherent mystery of things. The logical universe, cruel in its imposition of causal law, had to be destroyed. Those of his characters who are materialistic in outlook are represented as evil and destined to go down to destruction, for the machine is their doom. The hero of *The Plumed Serpent* symbolically stops time. By contrast the horse is, as with Robinson Jeffers, a symbol of all that is vital. Lawrence's return to Nature was based on forces that were dynamic, unconscious, organic. Although he implicitly trusted the creative unconscious, his conception of the unconscious was utterly unlike that postulated by the Freudians. Freud was a tiresome, mechanical positivist, not a man of vision. Thus Lawrence gave birth to the Holy Ghost of his own unconscious. All these things he knew immediately by intuition, and intuition told him unmistakably that science was dead wrong. As William York Tindall points out in his study, *D. H. Lawrence and Susan His Cow*: "For the way of the scientists and their absurdities about sun, moon, and bowels, he had substituted 'subjective science' based on the data of living experience." Lawrence's heroes are driven by vital energy streaming up from their solar plexus, without the intervention of the mind. As a vitalist, he wanted a world that was alive, dynamic, as opposed to the framework of dead matter constructed by the scientists. He welcomed change, irrationality, impulse, the genius of disorder, and deplored fixity, boundaries, limits.

It is not surprising that many intellectuals have turned to Lawrence as one who can guide them out of the wilderness. *Fantasia of the Unconscious*, like *Apocalypse*, is their Book of Revelation. Lawrence consistently attacked the scientific conception of the human body, refusing to accept a deterministic physiology, a mechanistic interpretation of the marvelously integrated, passionately responding body as composed of so many cogs and gears and wheels. The body could not be a totality of coordinated little automatons and conditioned reflexes. Such a notion of the body as functioning like a machine was utterly repugnant to him. No, the inexplicable

soul, the vital spark, the living god, came first. Even if the soul could not be defined, it is nonetheless there. This mysterious entity is the individual integrated self which no mechanistic scientific principle can hope to account for.

The obsessive Rousseauistic strain persists in the revivification of the primitivistic cult, the opposition to so-called intellectualized values. This, we are told, is the major disease from which modern man suffers so acutely: the effort to know himself, to capture his vital essence in the net of cognition, an effort that is bound to prove abortive. There is no proportion between knowledge and being. But is it not also true that to be and not to know may produce a pathetically uncoordinated creature of impulse? The pure instinctive savage is a myth. Lawrence realized that his exaltation of being, of primary, nonmental consciousness, must be supplemented by some form of knowledge. But he expressed it in a characteristically misty and mystical manner:

> Yet we must *know*, if only in order to learn not to know. The supreme lesson of human consciousness is to learn how *not to know*. That is, how not to *interfere*. That is, how to live dynamically, from the great Source, and not statistically, like machines driven by ideas and principles from the head, or automatically, from one fixed desire. At last, knowledge must be put into its true place in the living activity of man. And we must know deeply, in order even to do that.

As if aware that there is a great danger in going too far, Lawrence made this significant admission: he knew we cannot live by impulse alone, though the voice of organic consciousness, the self in its wholeness, should be supreme. The trouble with modern man, he held, is that he fails to act spontaneously and out of wholeness. Each one must retire to the stillness and solitude of his own soul. Only there can he find the clue to the universe. As for science, why should he give it complete credence? Its theories are pure speculation and he rejected them even though they seemed highly plausible. While trying, through scientific knowledge, to find a clue to the outer universe, he had "swallowed such a lot of jargon that I would rather listen now to a Negro witch-doctor than to Science."

The science, the subjective science that Lawrence was interested in calling forth, is as remote from the science developed in the laboratory as Plato from Pavlov. It is pre-eminently a creative science, a poetic affirmation, a subjective hunch. Scientific knowledge, limited in its references, is concerned only with phenomena that can be tied together in a causal relationship. Though science has made tremendous progress, it far from exhausts the whole scope of human possibility. Science gives us but the anatomy of a dead world, whereas Lawrence believed "in the strangeness and rainbow-change of ever-renewed civilizations." No proof was needed. That is the essence of his faith.

When Lawrence turned against Freud, he knew what he was doing. He was not only drafting a declaration of creative independence, he was also safeguarding his health and wholeness. The mind was not a cadaver to be dissected. Hence his strident emphasis on the passional consciousness, the knowledge that pulses in the blood, the instinctive imagery of primitive man. Having seen the light, he was not afraid to damn science or attack any knowledge that stood in the way of his creative salvation. He had no need to analyze or argue. This was his way of vindicating and deifying the function of the artist. Lawrence insisted that he was a novelist because he was a man supremely alive. And as a novelist he considered himself superior to both saint and scientist.

This religion of the instincts was intended to support his faith in the prophetic function of the creative artist. Though he had no coherent views to offer on the nature of art, he exercised a far-reaching and unfortunate influence by infecting many contemporary writers with his glorification of the untrammeled, native sensibility. The philosophy that called forth his most enthusiastic assent was the philosophy of primitive anarchism, the unconditional fulfillment of man's deepest desire without the distorting mediation of consciousness. Like a plant, he said, man has his roots in the earth, and he tears them up at his peril to dwell in the rarefied atmosphere of intellectuality. Salvation for the artist lies in returning to the womb of the unconscious. Man is not a creature of reason but of elemental passions. To be completely rational is to destroy the quick, spontaneous life. "What we want," Lawrence declared, "is a *complete* imaginative experience, which goes through the whole soul and body. Even at the expense of reason we want imaginative experience. For reason is certainly not the final judge of life." That, as he conceived it, was his mission: to rid the world of reason and to dispose of a science that is mechanical and objective and therefore dead. What could science give us but a confusing abstract formula, which disintegrates the essence of things?

Lawrence is typical of the antinoetic current of our time, the reaction against science on the ground that it is not only mechanical but devoid of values. Strong, indeed, is the impulse to embrace the mystical vision, the creative myth, anything that furthers life. It is significant that Lawrence felt it

necessary to fulminate against the scientific plague; instinctively he recognized it as the enemy to be overcome. Unfortunately, he failed to perceive that competing world outlooks are legitimate and fruitful, that science is no foe of the creative life, that actually it helps to foster the open inquiring mind and the democratic spirit.

The signal mistake of literati like Lawrence is that they attack science intemperately, without really understanding it. They fancy themselves in the role of crusaders sallying forth to slay a dragon, when the dragon is but a nightmarish image created by their own overheated imaginations. They project their anxieties and fears upon a universe of discourse that affords no basis for such paranoiac illusions, and it is the writers like Lawrence who lead the attack. It is not the scientists who spend precious time exposing the folly of the Laurentian cult, its experiments in irrationality, its antinoetic excesses, the crimes it commits against reason and truth in the name of vital fictions and intuitive "reasons." What is more, they refrain from pointing out how much Lawrence owes to the science he so savagely repudiated. For his very repudiation presupposes a fairly thorough study of disciplines like psychology, anthropology, psychoanalysis, and physics.

Lawrence simply left out of consideration the fact that there is no basic conflict between science and poetry, between scientific method and creative imagination. They are different, but not in conflict or contradiction. That is the fallacy which vitiates all his angry tirades on the subject. Moreover, he forgets that although the myths of the past have lost their force because people no longer believe in them, it does not follow that we must henceforth go impoverished and defrauded, mythless. Modern man in search of a myth—that is the epitaph that might well be inscribed over Lawrence's grave, together with the symbol of the flaming phoenix. The myth is man's perennial possession. The passing of one myth is the signal for a new gathering of forces, a renaissance of the creative thinking of the race. The new myths are about to be born, but it will be a long time before they establish themselves, take root, sprout leaves, and blossom and ripen in the sun of faith. The new myth of twentieth-century man is science, the most comprehensive, the most universal, and the most reliable "myth" fashioned by the genius of the human mind. It will nourish and support the creative imagination if it is but given a chance to make itself felt. The scientific myth will work, even if it will not work according to the specifications set forth by the literary mind, which is accustomed to the old sanctions and certitudes. Here is a myth, an interpretation of the phenomenal universe, which has this supreme distinction: it works! That is its only recommendation, it makes man face the truth: the truth about himself and the world he lives in. If it shatters many illusions he entertains about his specific "nature" and destiny, it confers on him truths and powers he cannot have on other terms.

Those literati who condemn science, on the ground that it is quantitative and mechanistic, lose sight of the fact that science, by promoting freedom of thought and freedom of inquiry and experimentation, is the greatest single force in the world today that makes for freedom. Actually, by espousing the scientific method and applying it to newer areas of experience, we are spreading the fruits of democracy. Unlike the men of the past, who were bound over to a belief in Providence and a conviction of their own insignificance and impotence, modern man has abandoned the idea of freedom of the will and replaced it by a faith in determinism. Though giving up the idea of free will, he has managed to adapt nature to his own needs and ends, transcending the imposed limitations of time and space and matter. Thus science has been the means of his liberation. Finally, it remains to prove that science is not indifferent to value, that it is profoundly concerned over the issue between slavery and freedom. The charge that science is rigidly deterministic, incapable of deciding for which ends it should be used, geared only to the determinism inherent in the causal pattern, springs from a fallacy in thinking, which equates science with mechanism. There is, however, no necessary duality, as Horace M. Kallen makes clear in *The Liberal Spirit*, in science and human values. Science is a cooperative, essentially democratic enterprise, its growth and progress dependent upon free consensus and open and extensive inquiry. There are no cherished values, no a priori truths, no preferential beliefs, no monopolies on truth, no special prerogatives, no hierarchical ideas. Perhaps that is why some writers have recently launched a campaign against what they call "the tyranny" of science.

Native Astronomy in Micronesia: A Rudimentary Science

WARD H. GOODENOUGH

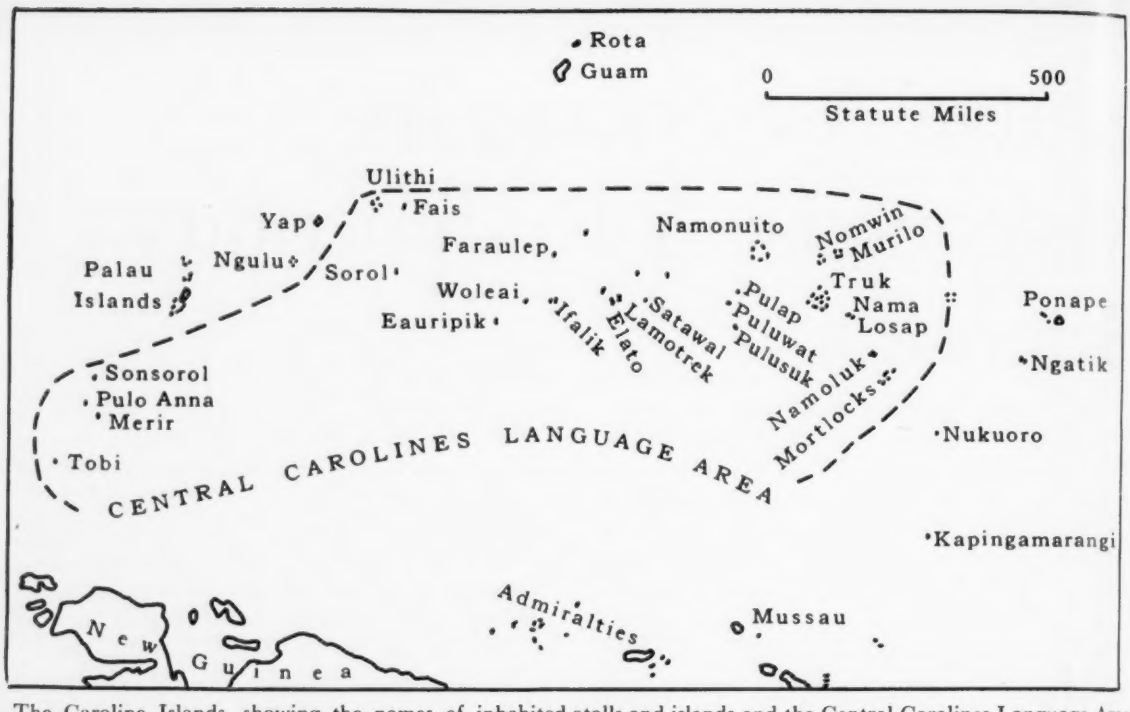
Ward Goodenough has been assistant professor of anthropology at the University of Pennsylvania since taking his Ph.D. at Yale in 1949. At the moment he is in the southern Gilberts as a member of the expedition headed by Preston Cloud. A six-man team, representing four different scientific fields, will spend three months in a general ecological study of the dry, heavily populated atoll Onotoa, under the auspices of the Pacific Science Board. At the conclusion of the study the author will go on alone to New Guinea for the Museum of the University of Pennsylvania, to conduct a preliminary survey among some of the island's upland peoples.

EARLY in the first world war the German governor of Truk in the Caroline Islands found himself unable to communicate with his superiors, all German shipping in the area having stopped. It happened that a canoe from Puluwat, ninety miles to the west, stopped in on a trading trip. At his interpreter's suggestion, the governor asked its navigator if he could get to headquarters on Ponape, 300 miles to the east. The navigator said he had never been there but was confident he could manage it. Not many days later he was back with replies to the governor's letters. The governor could well marvel that a simple loincloth-clad native could so confidently sail to a strange place without compass or chart and make the requisite landfall with pinpoint precision; the native, however, was merely applying a systematic body of knowledge of which he had to be master in order to qualify as a professional navigator. Astronomy formed a crucial part of this knowledge.

The more we know of it, the more interesting native astronomy in Oceania becomes as an example of a primitive science. Unlike the ancient astronomies of the Near East and Middle America, which were developed in response to the practical needs of agriculture, this one was stimulated by the exigencies of long-distance voyaging. Although the Polynesians are the best known of Pacific peoples for their intrepid sailing, their astronomy—whose remembered fragments have been investigated by Maud Makemson, of Vassar—provides few clues as to how such voyages were effected. Ancient chants speak of following particular stars, but poetic license ignores the fact that the earth's rotation would leave anyone following such advice literally sailing around in circles. If we leave the Polynesians and return to their more obscure Micronesian cousins further west in the Carolines, we find enough scattered information on their navigational methods that by pulling it together we can begin to see how navigation by stars was accomplished and what kind of an astronomy was developed for this purpose.

The Caroline Islands are a chain of tiny, scattered atolls extending east and west between the fifth and tenth parallels of north latitude for 1,500 miles. Most of them support only a few hundred people. At either end are the larger islands of Palau and Yap in the west and Kusaie in the east. In between, only the mountains of Truk and Ponape break the monotony of open ocean and occasional coral islets, so low that they are invisible from more than a few miles. Because of their meager resources, inhabitants of the low islands have always been forced to go to the few larger ones to trade. For several centuries Carolinians sailed annually to Guam in thirty-foot outrigger canoes to purchase iron tools and tobacco from the Spaniards, a voyage covering 400 miles of open sea. Native navigators have even visited such distant places as the Marshall Islands, New Guinea, and the Philippines.

Except for Palau and Yap, the various islanders



The Caroline Islands, showing the names of inhabited atolls and islands and the Central Carolines Language Area within which a more or less uniform system of astronomy is in use.

from the western end of the Carolines to the Mortlock Islands, a thousand miles to the east, all speak closely related dialects of the same language group (the central Carolinian branch of the Malay-Polynesian linguistic family). From island to island within this area the same system of astronomy is in use. It is, indeed, no exaggeration to say that regular intercourse between navigators has made possible the development of a truly international discipline, in which most of the local cultures share. It has even spread to a few neighboring islands with different linguistic affiliations. Beyond this, however, we encounter somewhat different astronomies, which indicate that what is found in the central Carolines is largely local in origin and not an import from a "higher" civilization in the Orient.

As elsewhere in Micronesia, astronomy in the Carolines is an adjunct of navigation, and knowledge of the stars is very largely restricted to professional navigators. As private, incorporeal property it is bequeathed from father to son and, among these matrilineal peoples, from mother's brother to sister's son. Anyone else must pay handsomely to learn it. Because of their knowledge, navigators stand at the peak of the native prestige hierarchy, and their persons are surrounded with numerous taboos.

There are two major aspects of the navigator's astronomy. From the location of stars he has derived a compass for expressing sailing directions, and from their movements he has developed an almanac and calendar. Stars and constellations are named only to the extent that there is a practical reason therefor, and position rather than magnitude alone is important in determining which stars are named. In this regard Carolinian astronomy resembles that of the Marshall Islands, where it is reported that many stars of first magnitude are without names, whereas many named constellations are composed of stars of from fourth to fifth magnitudes. This fact makes accurate identification of native constellations impossible without the aid of detailed star maps. It is largely responsible for the fragmentary and contradictory reports on Oceanic astronomy.

Because of their equatorial location, Carolinian navigators assume that the east-west axis of their islands forms the terrestrial equator and corresponds with the celestial equator. With visibility uninterrupted in all directions they make their observations with reference to the great circle of the horizon. The points at which stars rise and set (their azimuths) and the time order of their rising (their relative altitudes) provide the respective bases for the compass and calendar. At this latitude differences in azimuth and altitude correspond very closely with differences in declination and right ascension (celestial latitude and longitude). On

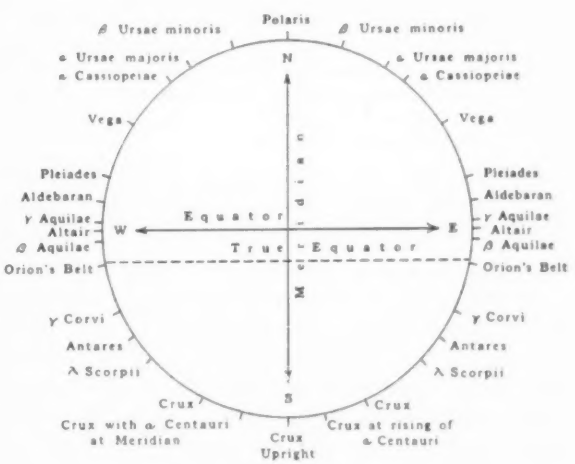
an east-west axis close to the equator, a perpendicular dropped from a star to the horizon will mark roughly the same latitude, regardless of the star's altitude. It is not surprising, therefore, that native astronomers treat azimuth and altitude as the equivalent of our declination and right ascension.

The east-west orientation of the Caroline Islands makes latitudinal sailing common, and their equatorial position simplifies the use of stars for this purpose. But not all sailing is latitudinal. Native astronomy must be capable of handling any and all directions. For this purpose navigators have selected a limited number of stars whose points of rising and setting provide the necessary coordinates for expressing sailing and wind directions. To go from island A to island B, for instance, one sails from the rising of X to the setting of Y. The prevailing wind of a particular season comes from the direction of the rising of Z, so that a navigator can orient himself in the daytime on the basis of wind directions and, with a like set of correlations, on the basis of prevailing currents. There are thirty-two such points on the horizon, each pair named for a star or constellation. The system does not depend for its operation on the visibility or immediate position of the stars for which these points are named. Other stars of similar declination will serve as well. The point of Vega's rising, for example, is fixed regardless of where Vega is. It is simply the type-star for which the point is named.

Within this system there are, as with us, four cardinal points. The North Star, which is just visible above the horizon, indicates north, and the Southern Cross in its upright position at the meridian indicates south. The line between these two points forms the native meridian and divides east from west. The declination of Altair in Aquila corresponds with the latitude of the Caroline Islands. In accordance with native assumptions, therefore, its rising marks due east and its setting due west. The line between the two forms the celestial equator separating the Northern and Southern Hemispheres. East is the first of the cardinal points, and the remaining positions in the coordinate system are reckoned from Altair north and then from Altair south, first in the east and then in the west. Following this scheme, the thirty-two points are marked from east to north by the rising of Altair Aquilae, Gamma Aquilae, Aldebaran, Pleiades, Vega Lyrae, Alpha Cassiopeiae, Alpha Ursae Majoris, Beta Ursae Minoris, and finally Polaris. From east to south are the rising of Beta Aquilae, Orion's Belt, Corvus, Antares Scorpii, Kappa or Lambda Scorpii, and Crux. The next point is marked by the position of Crux at the rising of Alpha Centauri, with south indicated by Crux upright. Points on the western horizon are named for the corresponding positions of the same stars and constellations. This system forms the navigator's compass.

We may wonder how such a compass can be effective, considering the fact that its relation to the true compass changes radically in different latitudes. Again we must remember that the position of the Carolines is latitudinally confined, so that the system remains in fact fairly fixed for the whole archipelago. The finer gradations on the east-west axis of the compass are further reflections of the latitudinal emphasis in native navigation.

That this star compass is standardized throughout the central Carolines is eloquent testimony to the large volume of traffic between the islands in this wide area. Although navigators jealously guard astronomical knowledge as a part of their professional secrets, there is obviously a free exchange of information among accepted members of the profession. It is taboo for navigators to eat any food except that separately prepared for them. Abroad as well as at home, therefore, they dine apart at the navigators' mess, where conversation inevitably turns to the circumstances of the latest voyage, the course followed, and weather conditions encountered. Taboo is too frequently regarded as a manifestation of religious superstition, with little attention paid to its constructive social results. In the present instance it has unquestionably served to foster and maintain the "free international exchange of scientific information."



The star compass of Carolinian navigators consists of 32 points on the horizon where certain stars are seen to rise and set. The declination of Altair, the base star, corresponds with the latitude of the Caroline Islands. Its rising and setting, therefore, indicate due east and west.

THE MAJOR NAMED STARS AND CONSTELLATIONS IN ORDER OF THEIR RIGHT ASCENSIONS, TOGETHER WITH THE MEANINGS OF THEIR NAMES WHERE TRANSLATION IS POSSIBLE

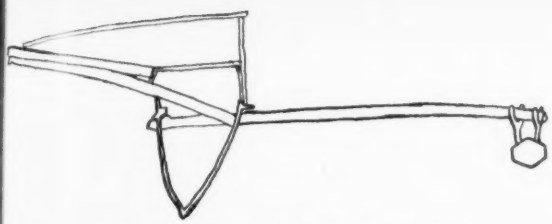
1. A large constellation called the "Fish," including Cassiopeia ("The Fish's Tail") and a number of unidentified stars to the south in Andromeda and Pisces.
2. Alpha, Beta, Gamma, and Iota Arietis, called the "Dolphin," whose swimming form it resembles on the eastern horizon.
3. The Pleiades.
4. Aldebaran and the Hyades, called "Testis."
5. Alpha and Beta Aurigae, called "North of Testis."
6. Delta, Epsilon, and Zeta Orionis (Orion's Belt), called the "Trio."
7. A large constellation called the "Bird," including Procyon (its "Northern Wing"), Sirius (its "Body"), and Eta Canis Majoris and Canopus (its "Southern Wing").
8. Alpha, Eta, Gamma, Xi Leonis, called the "Rat."
9. Alpha and Beta Ursae Majoris.
10. Crater.
11. Nu, Pi, Omicron Virginis.
12. Crux, called the "Trigger Fish."
13. Corvus, plus Spica Virginis.
14. Alpha and Beta Centauri, called the "Spear" because it is spearing Crux.
15. Arcturus.
16. Beta, Gamma, 5 Ursae Minoris, called the "Main Cluster of the North."
17. Corona Borealis, called the "Net."
18. Alpha, Tau, Sigma Scorpii.
19. Lambda, Upsilon, Kappa, Iota Scorpii.
20. Nu, Xi, Omicron Herculis, called the "Little Cluster."
21. Vega and adjacent stars in Lyra.
22. Alpha, Beta, Gamma Aquilae, called the "Main Cluster."
23. Alpha, Gamma, Nu, Xi Cygni.
24. Alpha, Beta, Gamma, Delta Delphini, called the "Bowl," the four stars resembling the outline of a native wooden bowl as seen from above.
25. Alpha Equulei.
26. Alpha Andromedae and Beta, Eta, and Mu Pegasi.
27. The Milky Way, called the "Breadfruit Road," reflecting the belief that breadfruit comes from a mythical southland whence conjurors must summon it each year if local trees are to bear well.
28. Polaris, called the "Fixed Star."

In line with this exchange it is customary for navigators to note on the star compass the relative location of all new lands encountered and to add this information to existing knowledge. As a result, the German ethnographers Damm and Sarfert obtained from a navigator on Puluwat a list covering several pages of fine print, giving sailing directions in terms of this coordinate system from every known place—including reefs—to every other known place. Each course is given both directly and with respect to a third island or reef forming a triangle with the first two, to provide another point of reference and an alternate landfall. Lands lying along a given axis of the compass are also known. This, coupled with the number of days of sailing by which they are known to be separated, has made it possible for navigators to astound Western observers with the accuracy with which they can make sketch maps of the Caroline chain. Since there are no written records, a professional navigator memorizes all this information. Thus, like the governor's courier, he can with some degree of confidence go anywhere in his world and know where he is when he sights land.

As any Western sailor knows, tacking on a fixed course requires that allowances be made for the loss of way resulting from the lateral pressure of the wind. Before we turn to the calendrical aspects of Carolinian astronomy, therefore, it will be pertinent to mention the ingenuity native canoe-builders have exercised to make possible long tacks on fixed compass points without loss of way. Their outrigger canoes are constructed with asymmetrical hulls, which are convex on the outrigger side but concave toward the keel on the opposite side. This is a feature that has long puzzled Westerners, though it has been assumed that it somehow compensates for the effect of the outrigger. Thanks to what Harry Payne Whitney learned last summer from a visiting native of Yap, we now have a fuller explanation, confirmed by the sailing performance of an architect's model which his Yapese guest constructed for him.

Carolinian canoes must sail with the outrigger always to windward. When they heel over in a stiff breeze the outrigger comes out of the water. If it were on the lee side and pushed under water, the canoe would be likely to capsize, the effect being similar to the results of "catching a crab" in rowing. On changing to an opposite tack, therefore, the lateen-rigged sail has to be reversed and what was the bow becomes the stern. Regardless of how a canoe is constructed, when its outrigger is out of water its performance cannot be the same as when its outrigger is subject to the water's resistance. It is precisely this fact on which native craftsmen have capitalized. The asymmetry they give to the keels of their sailing canoes is so calculated that when a canoe heels over it sideslips crabwise to windward. When allowed to right itself, it falls off to leeward. In sailing, therefore, a canoe's wake describes a gentle zigzag. The angle can be controlled by tightening or slackening the sheet, this being the method by which canoes are steered. In this way it is possible to sail on a given point, even on a sharp tack, without ever having to come about—an obvious advantage when navigating by stars.

Forecasting weather conditions has always been of as much concern to sailors as knowing where



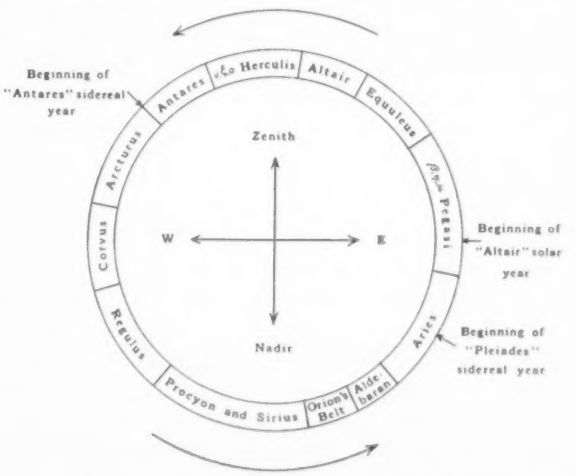
Sailing canoes in the central Carolines have asymmetrical hulls. The keel is convex on the outrigger side and concave on the other, not only in cross section but also fore and aft. The above sketch shows the hull, outrigger, and lee platform of a sailing canoe from Yap (after Müller, *Yap*, Vol. 1, 175 [1917]).

they are. It is in this context that the Carolinian calendar has had its major development. There are other contexts as well for keeping track of time. Seasonal variations in the breadfruit crop, for example, provide the basis for a feast-day calendar. The phases of the moon have given rise to a thirty-day lunar month, each day or, more properly, night of which bears a name in some way descriptive of the moon's appearance. The names used and their sequence approach uniformity in the various islands. The lunar month is divided into three periods of ten days each. The first ten, a period of darkness, are feared as the time when ghosts and sorcerers are active. The second ten days of relatively full moon during the evening hours are favored for social activities. The lunar month represents the longest day-count kept. For longer periods the calendar is a sidereal one.

Navigators use the stars to determine the time of year at which they may best undertake particular voyages. From the stars they know when to start preparing, what the prevailing winds and currents will be when they embark, and how long they can safely be away before starting home. For this purpose natives divide the year into eighteen or nineteen unequal periods based on the heliacal rising of particular stars and constellations. By correlating weather conditions with them they have developed what amounts to a sailor's almanac. It is not meant to divide the year into a fixed number of periods of equal length. It places a premium on defining as exactly as possible the times when weather conditions shift and within which they remain constant.

In addition to this almanac there is a shorter sidereal calendar, whose various local forms are all abridgments of the almanac and which contain fourteen or, more commonly, twelve time divisions. There has been an obvious attempt to equate the latter with lunar months. Divisions on the sidereal calendar are also called "moons," though they are named for stars. On most of the islands, however, the attempted correlation stops there. The divisions are of unequal length, and the names selected are those important in the almanac rather than those whose right ascensions are evenly spaced. Despite local variations, all such calendars have the same names for those "months" in which most sailing is done (Arcturus through Aries). They show less agreement for the period from May through October, when unpredictable winds, calms, and frequent overcasts make sailing hazardous. Emphasis on navigation has served to inhibit rather than promote more than a nominal equation of the lunar and sidereal cycles.

On only one island, tiny Ngulu, is there good evidence of a more serious attempt at correlation. The people of Ngulu have borrowed the central Carolinian astronomy from their neighbors, being themselves Yapese in speech. On Yap the calendrical system is different, and the year is divided into twelve or thirteen lunar months. Using the most typical abridged form of the central Carolinian almanac, the navigators of Ngulu have adapted it to the Yapese system. They divide the year into twelve lunar months, with a thirteenth for leap years, but arbitrarily name them for constellations following the sidereal calendar of their neighbors. Keeping the sidereal calendar as well, they have learned how the lunar and sidereal months of similar name change in their relationship to one another and use the extra lunar month to bring the two calendars back in phase in leap years. It is possible that the vaguer correlations in the central



The calendar most common in the central Carolines includes twelve star-months of varying length. Each month begins with the first appearance at dawn in the east of the star for which it is named. The sidereal year begins with the heliacal rising of either the Pleiades or Antares. Some calendars, therefore, name a month for the Pleiades. The solar year in the southwestern islands begins when the sun rises in the compass position marked by Altair.

Carolines proper reflect the beginning of a trend stimulated by the Yapese lunar calendar, for Yap, although not one of the central Carolinian islands, has exerted great political and cultural influence over them in recent centuries.

Native astronomy is aware of the year in a solar as well as a sidereal sense. In the westernmost islands, for example, the year is named for the constellation "Main Cluster" (Alpha, Beta, Gamma Aquilae), the rising of whose chief star, Altair, indicates due east. When the sun's position on the ecliptic is such that it rises where Altair does, the new year is said to begin. It continues to rise further to the north until it comes up in the compass position marked by the Pleiades. It then swings south until it rises in the position of Antares, whence it returns to Altair for the start of another year. Thus the "Altair year" is a solar one and begins with the native equivalent of our vernal equinox. In other islands navigators use a sidereal year, whose beginning coincides with the heliacal risings of either the Pleiades or Antares. Throughout the islands, however, native observers have noted that the sun rises and sets further to the north or south in relation to its background of stars, and that one complete cycle of this sort corresponds to the annual revolution of the skies. Since their points of reference are abstractions based on the directions in which stars rise and set rather than the stars themselves, they have not developed a zodiac of the ancient Near Eastern type, in whose twelve constellations the sun was actually seen to rise. Their knowledge in this regard, however, is no less, and if the zodiac stands as a monument to the careful observations of the Magi, the "Altair year" represents an equal achievement.

Curious as it may seem, native navigators appear to be little concerned with explanations of the heavenly bodies or their movements. They assume that the sun, moon, and stars go around the earth, which is fixed, and argue that if the sun, for example, did not move it would always seem to rise and set in the same place. But they have not deified any of the heavenly bodies, nor do they have an elaborate mythology seeking to rationalize them. The few myths reported are used more as an aid in remembering the composition and relative location of the constellations rather than as philosophical explanations of them. Practical and empirical in their approach, the Carolinian people belie the frequent assumption that man everywhere is awed by the marvels of nature and, stirred to speculate thereon, seeks to formulate a coherent theory as to the origin and meaning of the cosmos. Considering the intense native interest in divination and luck, it is equally noteworthy that the Carolines have produced no astrological systems. Rooted in navigation, aimed at determining directions and predicting the weather, native astronomy is perhaps too important for personal safety to permit its being removed from an empirical context.

The question arises as to whether we may justly consider Carolinian astronomy a science. The natives lack an adequate means for precise measurement. They have no geometry or algebra by which to express or calculate relationships. Lacking other symbolic systems, they must express everything in words, and simple diagrams sketched in the sand. They express little direct interest in theory, limiting themselves to empirical solutions to practical problems; nor have they made an attempt systematically to chart the heavens. On the other hand, their compass is a true abstraction. They have gone a long way toward systematizing their observations. They have inductively discovered that the stars rise and set in the same place on the compass in a given latitude, that a complete cycle of the sun on the ecliptic coincides with the annual revolution of the stars, and that neither can be evenly divided by lunar cycles. Moreover, they have acted on these principles, applying them to the solution of practical problems, and in the interests of systemization have begun to integrate the lunar with the solar-sidereal calendar. If less interested in theory, native astronomers have at least kept open those questions they could not solve, eschewing mythological or theological explanations. With a relatively free exchange of information they have fostered a growing discipline, which was clearly still in the process of development until within the past few decades the introduction of Western education and skills began cutting the ground from under it. Here, indeed, were the rudiments of a science.

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Science and Values: A Survey of Current Points of View

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THIS paper is a brief review, which does not exhaust the logically possible views on the relationship between science and valuation, but only attempts to cite those ideas that have been recently expressed by various specialists.

1. One view is so prevalent that it is probably no exaggeration to call it the conventional one. Statements of fact and statements of value are held to be logically distinct, and the former are the only ones that can be made by scientists. Scientists may determine the consequences of action, but they cannot make choices. This view seems to have been dominant in the history of science for the past three centuries. Indeed, its acceptance is so widespread that documentation seems almost superfluous. Among sociologists, Lundberg is representative of this position.[1]

2. Another theory regards science as providing the factual basis for effective valuation. (This is not necessarily inconsistent with the position just mentioned.) Judgments of value, from this standpoint, will be "correct" to the extent that they take into account scientifically established "facts" that are relevant to the particular valuing situation. Thus, one can find out from "science" what food is "best" for the human organism. The criticism is often made that this position tells only what means are effective to previously given ends; it cannot tell, to use the same illustration, whether the organism should continue to live. Stating the criticism somewhat differently, science cannot be a decisive factor in a situation where the subject feels he is choosing between alternative courses of action that are not comparable in terms of relative efficiency—or something of that sort. The most comprehensive formulations of this view usually relate it to a system of human "needs" or general psychological characteristics of the human organism. Once these needs or characteristics have been determined (presumably by psychology or anthropology), it is possible to evaluate institutions and so on as to their effectiveness in satisfying the needs, which may be arranged in some sort of hierarchy, as being not all of equal importance. One difficulty of this hypothesis, of course, is defining just what these human characteristics may be and, in particular, delimiting the role of culture in influencing them and the role of the scientist's culture in determining the manner of their observation, definition, and systematization. Hull, Fromm, and Malinowski (and others) might be mentioned as having made suggestions in this area.[2] R. E. Smith believes that values are part of "reality," which are discovered in experience and thus become knowledge, describable by scientific techniques. One can decide, "scientifically," what a person "ought" to do in a given situation—assuming that certain values are known to the individual as a result of his past experience—because of the biological and psychological character of man. Knowledge of values makes possible their rational selection.[3]

3. Related to this position is that of Weiss, who maintains that it is possible to arrive, by empirical analysis, at universal ethical standards, at things everywhere regarded as right (or wrong), and, presumably (this is my interpretation), it is then possible to evaluate less universal goals and means in terms of relevance to these common, pervasive principles.[4] (The anthropologist Clyde Kluckhohn seems to share this view.) Research based on the hypothesis seems to be nonexistent.

4. A fourth point of view has been developed re-

cently by F. S. C. Northrop,[5] who has investigated the possibility of a "scientifically verified normative social theory." Any normative theory, says Northrop, makes assertions (or contains assumptions) about man or nature that can be checked by scientific means. Any normative theory that makes false assertions, or contains false assumptions, is a false theory. For instance, a theory based on natural selection through unqualified survival of the fittest individuals is false to biological fact. The theory that includes the widest range of verified facts is the most nearly correct one. A correct normative theory will have postulates that are identical with the postulates of natural science. Not all values may be verified in this way—some are matters of individual preference, and so on—but some values and principles, Northrop believes, may be so verified.

5. Another point of view seeks the criterion of the good in "conformity to evolutionary trend." Julian Huxley and C. H. Waddington are among those particularly associated with this idea at the present time.[6] Although a similar criterion was used by Spencer and other evolution-minded sociologists prior to, say, 1920, the more recent formulations may be somewhat more sophisticated. At least they avoid the errors of assuming that recency is a criterion of "progress," or that the trend of events is an automatic process entirely independent of human desires or planning. The criticisms may still be made, however, first, that the evolutionary process may not present a consistent picture, but rather one of conflicting tendencies; second, that evolution may be of such a nature as to allow a great variety of alternative patterns of culture; and, third, that there should be some other criterion by which one can determine whether observed evolutionary trends are desirable. To these objections, part of the reply of proponents of the theory is that existence is its own justification and that the fact of evolution implies justification of a continuously more "comprehensive" existence. No other criterion, except a supernatural one, is available.

6. Some writers have dealt with what might be called an "ethical environment appropriate to science." Taking the value of science as established (perhaps in terms of "best method of problem-solving" or "most efficient satisfier of needs"), certain social arrangements or cultural practices are seen to be especially favorable for the development of science and therefore are to be encouraged by the scientist. Bowman points out that the "ethics of science," including such traits as intellectual honesty and respect for evidence, favors social changes that conform to these "rationalistic" characteristics—for example, intellectual freedom, freedom of the press, and absence of supernaturalism.[7]

7. In sharpest contrast to the conventional view first mentioned, there is the one particularly associated with John Dewey and the "naturalists," which seems to be largely a product of pragmatist and instrumentalist philosophy (in turn, of course, much influenced by scientific methodology).[8] According to this doctrine, which is not easy to summarize, values may be approached in the same scientific manner as "facts." Means-ends or means-consequence relations are empirically verifiable. Values or interests are regarded as hypotheses, capable of the same sort of test as other hypotheses. An experimental attitude is stressed.

It should be emphasized that the preceding classification is somewhat arbitrary and that a given individual might be placed in more than one category. The classification may serve, however, to bring out some of the differences that seem to exist among writers on these topics, and that is its chief purpose here.

It seems significant to this writer that workers in a number of academic disciplines have, in very recent years, expressed dissatisfaction with the traditional separation of facts and values.[9] This dissatisfaction may doubtless be attributed to problems created by technological advances and to new scientific theories that cast doubt on older religious or metaphysical theories—from which traditional value systems largely originated—and to problems associated with the social science concept of "cultural relativism," according to which values are entirely a matter of cultural definition. In an age in which science and rationality are all-important, many people are unwilling to accept values simply on the basis of faith or precedent. The lack of any other accepted basis for value judgments may thus result in personal disorientation or social disorganization. This has been one of the major effects of an increasing use of the scientific method. Some scientists are now making efforts to arrive at a methodologically and socially more satisfactory approach to judgments of value. A detailed analysis of the contributions of sociologists, psychologists, anthropologists, and economists to this topic would reveal additional problems and approaches.*

* This article has given relatively little attention to the thoughts of philosophers, who are the conventional guardians of the subject. An important collection of essays on value, by philosophers, is that made by Ray Lepley (Ed.), in *Value: A Cooperative Inquiry* (New York: Columbia Univ. Press [1949]).

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Ernest Solvay, Father of the Alkali Industry and Social Crusader

CHARLES S. GLENN

On leaving MIT, the author entered the employ of The Solvay Process Co., the American member of the association of companies organized and directed by Ernest Solvay. Mr. Glenn was with the companies for more than twenty years, in America, Great Britain, and Europe. In 1930, after Solvay's death, he joined the Mathieson Alkali Corporation, of which he eventually became vice president. In preparing his article, he had the assistance of the present Ernest Solvay, grandson of the founder, and of André Desoer, of the central organization.

THE names of Thomas Edison, Henry Ford, Andrew Carnegie, and Alfred Nobel are widely known among us. Their contributions to industry were of prime importance to Western civilization and to the growth of industrial America. Of industrial stature equal to any one of these, and one whose contribution transcended the material and had a strong impact on the science of human relations, was the Belgian, Ernest Solvay, father of the modern alkali industry and lifelong crusader for the betterment of the average man. Although we in America have benefited greatly from Solvay's genius, he is almost unknown to us, even by name. This article will attempt to depict the man, his philosophy, and his accomplishments.

Ernest, born in 1838, at Rebecq, Province of Brabant, Belgium, was one of the five children of Alexandre and Adele Solvay. The family, of Walloon origin, had occupied for many years an important place in the industry and in the educational field of Brabant. The children, surrounded by an atmosphere of culture, service, and liberalism, were fine examples of the influence that such an environment, extending over several generations, may have upon the individual. Alexandre Solvay, operator of a marble quarry, a saltworks, and an importing business, was widely read in spite of the difficulties of access to literature at that time. His philosophy appears in the maxims he recorded, of which the following are typical:

A good book, a good conscience, and a household at peace within itself are for a man an earthly paradise.

Good sense is the most important of the qualities of the mind.

Man's error is that he fails to put himself in the place of those upon whom he passes judgment.

Work is a debt that all of us owe to society.

Young Ernest, though of frail physique, was nevertheless a very active child both physically and mentally. His curiosity as to the why of things was insatiable, and he was given to experiments, sometimes of a mischievous nature. He led his classes in school. His parents planned for him an engineering education; but before he was ready to enter college he was gravely threatened with pulmonary trouble and was obliged to leave school and return to his home in Rebecq for an indefinite period of rest and recuperation. Meanwhile his younger brother, Alfred, who afterward became his second self, went on to an engineering degree.

While at school Ernest had become infatuated with the study of chemistry. Now, condemned to the quiet life of Rebecq, he devoted himself to self-instruction and experimentation in that art, and to this end he built a small laboratory. His lack of personal contacts and study with competent teachers of chemistry and physics left him in after-life with a certain sense of technical deficiency; on the other hand, the same factors aided in the development of his creative judgment and self-reliance.

As he regained his strength, Ernest sought em-

ployment in some technical or engineering line. One of his relatives, a Mr. Semet, had a gasworks near by and offered him a job in which he could learn the process. He accepted this and quickly drew attention to himself by his suggestions for improvements in operating procedures.

The chemical industry was then in its infancy, and there was little market for many of its by-products. Ernest set himself the task of finding a use for those of the gas plant, of which ammoniacal liquor appeared to be one of the most promising. He was familiar with his father's salt plant and from his reading and experiments knew that carbonic acid gas would combine with aqua ammonia. For him it was natural to try mixing the three substances. When he did so he got a white precipitate which he determined was a carbonate of soda. He believed that he had discovered a reaction till then unknown, that he had invented something that might not only be the means of utilizing the ammonia being wasted at the gas plant and some of the salt manufactured by his father, but might also reduce the cost of soda, then produced by the Leblanc process, and selling at 700 gold francs ($150) the long ton.

In 1861, at the age of twenty-three, Ernest obtained a Belgian patent on his invention, and he and his family decided to embark at once upon the manufacture of soda. Alfred was recalled from England, and the family got together funds for constructing a pilot plant in an old abandoned factory building near at hand.

Ernest, assisted by Alfred and a boyhood friend, Acheroy, designed and built the pilot plant and attempted to operate it. The design came out of the blue—not one of the constituent steps had been reduced to practice. Surely the Solvay family had undertaken the project with the valor of ignorance. Nothing functioned as expected, and, in addition, there was the peril of asphyxiation by escaping ammonia gas, a peril that the industry is mindful of even to this day.

In a year's time, 35,000 gold francs, all the money available in the family, had been spent, and the reduction to practice had only begun; nevertheless the group had faith and decided to seek outside capital. Certain industrialists were approached and found skeptical. Solvay thought it advisable to retain legal counsel. He chose a Mr. Pirmez, who naturally suggested that a search be made to determine the value of the patent. This search disclosed that in 1811 the great physicist Fresnel had discovered and called attention to the ammonia-soda reaction. He saw possibilities in it but did not pursue them, since disposal of ammoniacal liquors was not important to him and since the Leblanc process was practical and profitable. In 1838 two English chemists, Dyar and Hemming, had filed application for a patent on an incomplete form of Solvay's invention. An agent of theirs followed this in 1840 by an application in France of a fairly comprehensive form, describing the process about as visualized by Solvay. These patents were issued, and from then until 1860 prominent English and French industrial engineers and chemists—especially two well-known French engineers, Schloesing and Roland (1858)—had attempted to put the process to commercial use. Considerable tonnages of soda had been produced, but difficulties and costs were discouraging, and all attempts had finally been abandoned.

On learning this, Solvay, shocked and for the moment hesitant, consulted the noted Belgian chemist Stas, who told him that his process required the careful nursing that could be given it only by chemists in a laboratory—it was too ticklish for industrial application. By now, however, Solvay's determination and self-confidence had again risen to their norm. Moreover, Pirmez took an optimistic view, and turned the disheartening example of the repeated failure of predecessors into a reason for courage, arguing that since competent industrialists had spent so much time and money in attempting to reduce the invention to practice it must have great promise, if only it were exploited by a genius in the industrial application of chemistry. And was not Solvay such a genius? The family agreed with Pirmez that he was.

New efforts were made to raise funds. Solvay estimated that by his process the cost of soda would be about 175 gold francs ($35) the long ton. For a product then selling at 650–700 francs this sounded like wishful thinking to the men with the necessary money; but, finally, through his persuasive personality, Solvay obtained the funds he sought.

In 1863 a closed corporation, Solvay et Cie., was formed with a capital of 136,000 gold francs. It was decided to build the definitive plant at Couillet, Belgium, alongside a railroad and near to coal mines. A long-time contract for ammonia was signed with a gas company, and a patent covering the production apparatus and its arrangement was obtained. Solvay gave up his job at the gasworks, to devote his entire time to the new plant.

All of 1864 was required for plant construction, and operations began in 1865. Then ensued five months of struggle, with the Solvay brothers and Acheroy on the job night and day, getting what sleep they could in the plant itself. At the end of that time daily production was less than a quarter

of a ton. Then one of the principal pieces of apparatus ripped apart. It had to be rebuilt and they had already used up all their capital and were in debt. Fortunately, Alexandre Solvay had just received a small legacy which he now turned over to the company; the apparatus was rebuilt of improved design. It functioned well. But just then another important machine failed. This was the end and the family knew it. So did the other members of the company; they refused to subscribe more funds, and forced liquidation seemed at hand. The necessary papers were drawn up for a petition in bankruptcy, and the family gathered at Rebecq for the signatures. But Adele Solvay would not submit to such a stigma on the family name. They must all of them scrape the bottom of the barrel, she said, and contribute the last remnants for a final, supreme effort. Her courage and fire carried all with her. If she could look penury in the face, why should any other hold back? The family's small remaining funds were contributed, and the plant was returned to operating condition.

This time things were different. The worst "bugs" had been removed from the apparatus. Output increased. In June 1866 it had reached 1.5 tons per day, and within a year it was 3 tons per day. Costs were as predicted. The Solvays had succeeded where others of much greater reputation and financial resources had failed. What were the difficulties that had defeated their predecessors? They appear to have been as follows:

1. At the time ammonia was an expensive product whose principal source was sewage. Recovery of ammoniacal liquors from gasworks had not been developed. Recovery of a high percentage of the ammonia employed as an intermediate agent in the process was recognized as essential to reasonable costs, and success in such recovery was gravely doubted.

2. Chemistry was still largely a laboratory science. A chemical engineer, such as Solvay, was a *rara avis*, born and not made. Successful handling of the large volume of liquids, slurries, and gases, which the process required, seemed too difficult to the laboratory technicians of that day.

3. The essential reactions of the process are comparatively slow in plant-size apparatus and require fairly close control of concentrations, temperatures, and pressures. The designs of Solvay's predecessors had been poorly conceived for such controls.

When Solvay began the reduction to practice of his invention he was already experienced in the handling of ammoniacal liquors on a plant scale and in ammonia recovery. As operations proceeded he was quick to diagnose the malfunctioning that developed and to prescribe the remedy. But above all was the clear vision and the indomitable belief of the man in the worth of his process, a faith that he was able to communicate to his family and to everyone else. Moreover, he was sustained, helped, and encouraged through all his difficulties by a loving and devoted wife who guarded him from all domestic cares and was the admirable companion of his whole life.

Growth of the Solvay Company. Once the Couillet plant was upon its feet it became a thorn in the flesh of the group of heavy chemical industries which had grown up around the Leblanc soda works as a source of its raw material, and which constituted at the time the whole of the *grande industrie chimique*. A strong effort was made to scuttle the new producer by reductions in the market price of soda. By 1870 the price had been knocked down to 350 francs; but Solvay's costs were right and his product was much purer than Leblanc's. He met every price cut and went one better. He could take over any customer he had the product to supply.

In 1872 the French plant at Dombasle was started, and in 1874 the English plant at Winnington. By 1878 Solvay and Company was rated as a major enterprise, and its success was widely advertised. By then the ammonia-soda process was known as one of the two most important contributions to industry of the nineteenth century, the other being the steam engine. Additional plants were built in France, England, the United States, Germany, Russia, Spain, Austria, Italy, and Switzerland, about in the order named. By the time World War I broke out there were twenty-four plants in the Solvay system.

Reduction in the price of soda caused a great increase in consumption. In 1887, Leblanc produced its all-time high of 540,000 long tons. Solvay's production was somewhat less than this, but the year following it took the lead. From then on Leblanc passed rapidly out of the picture; its defeat became a rout.

Solvay held that the ammonia-soda process was an art and he, the artist, was not to be constrained by thoughts of dividends. He must have free rein to improve efficiency in use of materials and of labor even beyond any point of diminishing returns, for because of changing conditions, that point tomorrow might have greatly advanced. The goal in plant operations must always be a close approach to maximum theoretical efficiency, and in the laboratory one must constantly seek a means of raising that maximum.

Solvay did not confine himself to dreaming of his high industrial objectives; he took prompt and vigorous action for their attainment. In doing so he showed consummate ability in industrial organization. Far ahead of his times in his concepts of inter-

departmental and interplant coordination in a great international union of plants such as his, he saw the necessity of creating the composite technician by the amalgamation of the engineer, chemist, physicist, and operator, four different types of the technical mind that must be taught to work as one —and not only that, this composite "one" must act in harmony with the nontechnical branches of the business. The success of his efforts was phenomenal, a monument to his leadership and to the compelling influence of his personality upon the outstanding staff that he built up. It is worthy of note that no one outside the Solvay system has as yet made a major contribution to the ammonia-soda art. On the other hand, all ammonia-soda producers have followed Solvay's advancing practice as fast as they have learned of it.

Starting in 1866 with a production at Couillet of about 500 tons per year, at a time when total world production was under 50,000 tons, the Solvay association produced in 1922, the year of the death of its founder, a total in excess of 3,500,000 tons. In the same interval the market price had fallen from $150 per ton to under $20, and quality had been enormously improved. In the years since then there has been still further surprising growth.

The value to mankind of unlimited quantities of soda products of such price and quality is self-evident when one realizes the direct part they play in daily household use, and the dependence upon them, as a raw or semifinished product, for the manufacture of soap, glass, textiles, rayons, oil refining, and chemicals from petroleum, dyes, fertilizers, and pharmaceuticals—a list too long to enumerate here. At every step of our daily life we make use of products that are within our reach because of the ammonia-soda process.

In spite of its enormous growth, the Solvay Company of Belgium remained a closed association, with neither common nor preferred stock. Title to fractional rights in the underlying equity was conferred by written memorandum and could not be transferred except by permission of the other owners. We see here a strong resemblance to the Ford Company, with its family ownership of the stock, and Solvay seems to have had the same distrust that Henry Ford had of banker influence in industrial management.

Solvay, engineer and scientist. In 1858, at the age of twenty, Solvay stated his conviction that energy, like matter, had mass, and that the two were interchangeable. He explained the latent heat of substances by saying that this phenomenon was a conversion of energy into mass. Given the proper instruments, he hoped someday to prove his theory. But for the next twenty years he was absorbed in the development of the ammonia-soda process. It was 1878 before he had brought his company to a position of such stability that he could devote much time to his preferred avocation, theoretical physical chemistry and its use as a base on which to build an ideal social system. From that time on the avocation became more and more the occupation that gave meaning to his life.

Now he returned to his theory that energy had mass. He discussed the matter with Stas and found him nonreceptive; but Solvay stuck to his belief. In the effort to obtain experimental proof he invented several machines of high precision and worked three years, with negative results. Finally he concluded that the equivalent mass was too small to be measured; perhaps only mathematical calculation would one day determine it.

Solvay believed that it would be possible to establish a few great, comprehensive laws by the aid of which all phenomena could be explained. He sought to aid in their establishment by reasoning and deduction. He visualized a lattice of natural laws, the close meshes of which would contain all nature, including the ancestry of the cell, the physiology of the atoms. He had the intuition that the atom deforms near-by space, and saw this atom as a spherical structure of cubes, cellular, discontinuous, held together by Newtonian forces. He saw the universe as closed upon itself so that beginning and end were inconceivable; a hermetic sphere from which nothing could escape; matter acting through Newtonian forces holding energy endowed with mass; profound order harmonizing all things, and they simple in their substance, but complicated in their interplay: the whole blending in incorruptible harmony.

It is apparent that Solvay did not conceive of time other than as subjective, and that his concept of space deformation by the atom consisted of a change from classic space to cellular, whatever that might be. This concept was arbitrary and he advanced no proofs. He believed that human consciousness is capable of comprehension of all that exists; that nothing can escape its perception, and that the laws of its being also govern the universe. He postulated that, in the final analysis, the living being is necessarily a physicochemical reaction obeying the laws of maximum work, and that consequently man and society as a whole are such a reaction, of which the base is energetics and production the form.

Solvay also believed that the day of ultimate solution of the laws of chemical synthesis was near at hand; he wrote: "After the betterment of our

existence that will result from progress in chemistry and in the utilization of energy, the conquest of the atmosphere and, after that, of the synthesis of organic foodstuffs, and others that we clearly see, what will there remain to do of any value? Nothing!" Beyond this he did not seek an answer; but set himself to the task of bringing closer that fateful day of "nothing more to do;" a day he could not hope to live to see, nor for himself desire.

Although Solvay's inquiring mind thus speculated as to underlying reality and had glimpses of theories that were destined to revolutionize science at a later date, we should not think of him as a genius in the Einsteinian category. He was self-taught, and the base of his scientific knowledge lacked breadth. Also his mathematics, that important tool of the modern scientist, lacked profundity. He reasoned well but often started from inadmissible premises, which he maintained with the tenacity that was of such value to him in building a world alkali industry. A mind such as his is not subject to the inherent doubt of that of the pure scientist. The premises that it has adopted are to it the best—or even the only ones admissible. Then, too, his speculations always had a very practical objective—the establishment of physicochemical theorems on which to build a new and better civilization. He was fundamentally the engineer, the employer of men, the organizer of industry. Of the two sides of his nature—the savant and the man of action—it was always the latter that predominated; his speculation led to action.

For all his sureness of himself, Solvay saw clearly the necessity of assistance in attaining his great objective. He said:

> I must confess that I am not a savant. I have never had a classic education, but I dare to have the ambition to aid in the creation of modern science. I must confess that at times I am aghast at my own temerity and how it exposes me to severe criticism by those who do not understand the height of my objective, the humility of my thought and especially the ardor of my convictions.

For many years he had dreamed of an institute for research and instruction. Now, in 1888, he took the step and founded at Brussels what later became the Institut Solvay d'Electro-Physiologie, with Paul Heger as director. Of this he said, "Physiology is the first of the social sciences; it tells us what man is and whence comes his energy; it explains to us the physical phenomena which are at the base of his intelligence, and in these phenomena electricity plays a preponderant role." A few years later he founded the Institut de Sociologie, concerning which he remarked, "The laws that society makes should not be made for fictitious and nonexistent man. They should respond to the living reaction, that physiology reveals to us, so that the maximum benefit to this reaction may be obtained." In 1903 he founded the Ecole de Commerce, for the development of new procedures in the distribution of the products of industry. In 1911 he formed the International Institute of Physics, over which Lorentz presided, and in 1913 the International Institute of Chemistry, with Sir William Ramsey and Sir William Pope. He counted on all these as instruments for the attainment of his goal of perfecting physicochemical theories and their application for the betterment of the social order.

Solvay, social crusader. In 1870 the Couillet plant was firm upon its feet, but the year brought in a period of great unrest in Europe. France was invaded by the Germans; there was the Commune and the overthrow of Napoleon III; the Internationale of the workers, among whom there was great misery, brought about by their displacement through the increasing mechanization of industry. A general staff of social revolt formed, in which were grouped those of high purpose and ability, side by side with others of limited intelligence, destructive and fanatic. The result was confusion worse confounded. The masses, crying for action, were ready to take any step to appease their misery. They cried out for the overthrow of the social system, the tearing down of the capitalistic structure as the Bastille had been destroyed.

Ignored a hundred times, never solved, the social problem now became world-wide. In Belgium there were strikes and rioting; the countryside was laid waste by bands of workmen gone berserk; troops were called out, and there was mutiny; hundreds of lives were lost. As a spectator of all this Solvay saw clearly that its causes were the development of material things at an unheard-of rate, while the intellectual rested *in statu quo*. From this flowed complete maladjustment between the component parts of the social system. Readjustment was necessary. For new times new morals were required; the democratic ideal forbids that great wealth and great misery exist side by side. Social progress required the satisfaction of the personal interests of the average man; that is, the satisfaction of the greatest possible number of his material wants. It was false to believe that there has ever been overproduction; proper distribution was the only problem. Reoriented society must recognize that the Christian maxim "Do unto others as you would that they do unto you" is a call to rational egotism that everyone should heed. Social conflicts were, for the most part, the result of the disregard by the masses and by the privileged of this fact—a disregard derived from ignorance.

Reasoning thus, Solvay said, "Society is sentenced to do justice to all, under pain of death." And he asked himself, "Can the awakening of universal conscience to the necessity of far-reaching reform, be best accomplished by the Church?" He gave close attention to its preachings in those times of travail and decided that it was impotent. He saw in its theorems of the abjectness of man a denial of human dignity, and in the entry of the clergy into politics a grave evil. It devolved on science to reorient society and it had the duty not only to produce riches in large abundance but also to solve the problem of their equitable distribution.

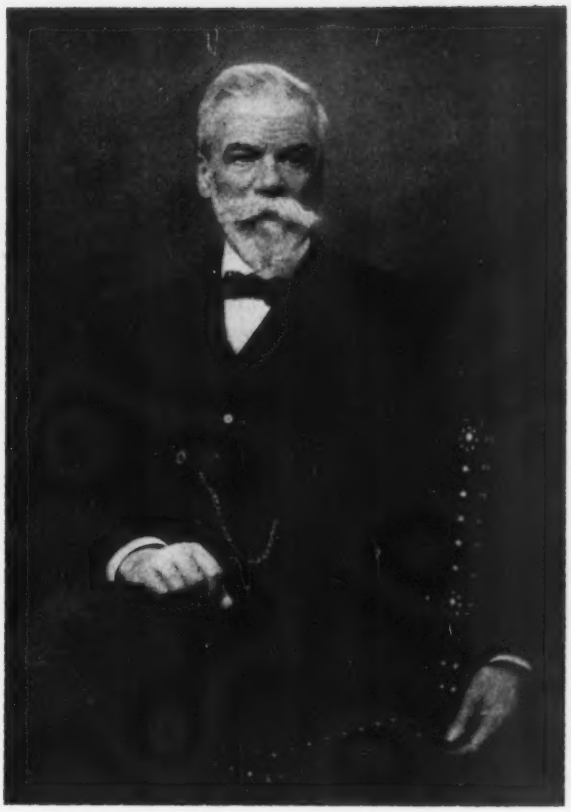
Solvay gave to his concept for the reorientation of society the name of *Productivisme*. "To be a productivist," he said, "is to recognize that the right path to pursue to assure the well-being of men is to develop by all the means of production, the things material or immaterial that he desires, and will desire in ever increasing quantity."

As a first step toward the new order, Solvay advocated the broadening of education to include all the people.

> The State [he said] should offer to every child the opportunity for full intellectual development that it may rise as high as possible in the social hierarchy. At present by the hazards of birth, some are thrown naked into the arena, others are armed cap-a-pie. This system, which too often gives decided advantage to the less apt, is inevitably doomed to disappearance.

Solvay recognized the wide variation in the capabilities of individuals. For him the true democracy was an aristocracy of the intelligent, devoted to service, and in which every man would receive according to his contribution. He visualized a change in the laws that would prevent the maintenance through inheritance of a class devoted to luxurious idleness.

But, in Solvay, the crusader was closely joined with the practician. It could not be otherwise with the engineer who by his genius had successfully developed a basic chemical process where many before him had failed, and who had then expanded it into the first great international chemical association that has withstood two world wars, communistic attack, and confiscation, a world depression, and is still without a peer in its field. He knew that the social reorientation that he believed necessary and inevitable was a matter of several, perhaps many, generations. Moreover, he did not visualize as final outcome the authoritarian socialistic state. He said, "It is an illusion to suppose that the working class once in possession of full political power could expropriate the capitalists without disaster. Suppression of private capital is easily said; but it is only words. Such a program is impractical." But in retaining private capital he thought it necessary that the industrial personnel share importantly in the profits and, perhaps, in management.



ERNEST SOLVAY (1838–1922).

Solvay knew that one preaches best by example, and in the plants under his control he adopted many social betterments. Among these were, for the workmen:

1. In 1889 a pension system paying ten times the rate then paid under state law.
2. In 1908 the eight-hour day.
3. In 1913 vacations at double pay.

For the supervisory staff there was instituted, at an early date, a system of participation in dividends paid, this sometimes amounting to more than 100 per cent of salary.

In the latter part of the nineteenth century, in spite of his abhorrence of publicity, Solvay decided that it was his duty to enter politics, in order to better preach his concept of *Productivisme* and further its adoption. He became a member of the Belgian Senate. There he allied himself with no faction, but with great sincerity, and often in loneliness, told his beliefs as to the necessity of a democratic enlightenment. He remained in the Senate until it was disbanded because of the German occupation. He then became active in the program

of feeding Belgium, in which he participated until the end of the war.

The life of Ernest Solvay is unusual in its lack of anecdote. Viewed in proper perspective, the details blend together and form a background that focuses the high lights on the unique motif of his personality—maximum efficiency in all things. This efficiency he imposed upon himself, as when at the age of fifty-seven he felt his physical and mental energy weakening through overwork, he took up the hard discipline of the Alpinist, a regimen of daily walking in all weathers, and, once a year, an ascent of some of the most difficult and dangerous peaks of the Swiss Alps. He never relented in this conditioning and even at the age of eighty-one climbed the Pizzo del Diavolo at St. Moritz.

Until past forty, Solvay was engrossed in the creation and bringing to highest efficiency of the world's soda industry. His phenomenal success in this in no way satisfied him. The golden stream that flowed to him itself called for efficient utilization in the development of *Productivisme*. There was no hoarding of gold, no Fort Knox in the Solvay thinking. Still less was he interested in the rigging of stocks in the security markets of the world. All such activities were to him anathema; money was a tool, not an end.

The last forty years of Solvay's life were devoted to the furtherance of his productivist theories. These demanded the advancement of science and its application for the establishment of social concepts that would raise human output to a maximum. But much as he would have desired it, he was unable to escape the homage that is showered on men of brilliant accomplishment. The Berlin Academy of Science made him an honorary member and gave him the Leibnitz Medal. The Royal Society of London decorated him. France gave him the Lavoisier Medal and the Grand Medal of the University of Paris. Leopold II offered him a peerage, which he begged leave to decline, preferring to remain the simple "Monsieur Ernest" that his employees called him. He set store, however, on two simpler honors: an honorary membership in the Association of Engineers of Liége and the doctorate *honoris causa* of the University of Brussels. At the end of World War I, King Albert, in recognition of his services during the German occupation, named him Minister of State. As such he addressed to the Peace Conference at Paris, where the nations were attempting to lay the foundations of a new world, a memorial calling attention to the need of laying the foundations of a science of social organization, "for without such a science there is only an anarchy of ideas, gropings and collisions, for we cannot see where we go."

All his life Solvay retained his simplicity. He cared for neither luxury nor ostentation. He was without "side." To the day of his death, at the age of eighty-three, he retained his activity and keenness of intellect. His life of serene and steadfast purpose, devoted first to the establishment of a world soda industry and afterward to the betterment of humanity, is, especially to us in America, an outstanding example of a great industrialist consecrated to social causes.

Science! Thou fair effusive ray
From the great source of mental day,
Free, generous, and refined!

—Mark Akenside, *Hymn to Science,* 1739

Three Poems *by* Daniel Smythe

HEAT

Related to the sun deep in each vein,
All things have known the throb of her warm thread.
The powers of April and the warm, full rain
Are in the sun-streaks that race overhead.

Heat was the first great thrust that moved the vast;
Heat is our burning sun that joined with space.
And all the trembling life that holds it fast
Responds with old delight to its embrace.

There are uncharted wastes of air and skies—
They move with wing and cloud and meteor;
And also earth is one brief dust that flies
Across the unknown gulfs, flame at its core.

And we, with heat within us, like the earth,
We trace the stabbing message of the skies,
And know the uncooled ocean for its worth
That in so many ways we recognize.

CITY IN THE TALL NIGHT

In the vast pocket of dark space
The earth's side has a star of light,
A tower of the electric race
Which probes the velvet of the night.

These buildings and these searching beams
So full and clear, a cameo
Of stars, now rise in pulsing streams
To deeps we cannot ever know.

A rug of blackness prickled by
The fingers of a wavering star—
We see the city roam the sky
And hurl its message broad and far.

LECTURE ON PSYCHOLOGY

"Students, heredity depends on genes,
And don't forget what homeostasis means!"

The reflex arcs are touched upon with awe,
With formal discipline and Weber's Law.

When integrative cones rain down on us,
He puts a strain upon the thalamus.

The maturation of the neonates
Plus classical conditioning, he states.

The hearer does not live who dares to scoff
At functional autonomy left off.

When his cerebral cortex speaks no more,
We walk away, no wiser than before.

SCIENCE ON THE MARCH

NEW ARCHAEOLOGICAL SITE IN PANAMA

A PREHISTORIC burial ground, located on the seashore only four and a half miles west of the Pacific entrance to the Panama Canal, was accidentally exposed when a bulldozer, in search of black dirt for surfacing lawns, began stripping off the topsoil.

Samuel K. Lothrop,[1] in his extensive work on the Coclé culture, estimated from the evidence at hand that the expansion of the Coclé Indian territory did not extend eastward toward the Panama Canal farther than Chame Mountain. The Canal Zone, which is about forty miles east of Chame Mountain, was considered by Lothrop to have been part of the territory which was under the influence of the Darien culture. In the Peabody Museum reports, Dr. Lothrop points out that a few pieces of Coclé pottery were found at Taboga Island, but he considered that they were trade pieces. Taboga Island lies about seven miles offshore from Venado Beach, where the burial grounds were uncovered.

When the Panama Society for the Advancement of Archaeology and Natural Science was advised of the new burial site, it investigated and found an extensive bulldozed area literally covered with broken pottery and fragments of human bones. Many of the potsherds were of unusual polychrome design, and the society took immediate steps to salvage the archaeological material missed by the bulldozer blade.

Knowing that the Venado site was in a region that reputedly was dominated by the Darien culture, the society members were surprised to find pottery that was identical in shape and structural plan to the Coclé ceramic work and having the same artistic designs, as well as identical color combinations. At first it was thought that this might represent a great Indian trading center where a large amount of Coclé material had accumulated in possession of some of the chiefs. As the salvage operation produced more evidence, however, it became overwhelmingly apparent that practically all the pottery was of the Coclé culture. The polychrome, buff, smoked, incised, red, and black-on-red ware—in fact practically every type of Coclé pottery classified by Dr. Lothrop—was represented. If the photographs of the Venado Beach pottery were mixed with those of the Coclé ware, it would take an expert indeed to distinguish one from the other. A similar comparison of other material shows the metates, the stone celts, coral and gold beads, carved bone, ivory, and mother-of-pearl, and seashell ornaments, as well as many other types of artifacts, to resemble the Coclé culture in nearly every detail.

The Venado Beach graveyard was laid out on a level plain much the same as at Coclé. Direct measurements could not be made in the disturbed area, but careful estimates show that the bodies were buried from four to eight feet deep. Most of the shallow graves had been partially, if not totally, destroyed by the bulldozer. Some bodies were laid out full length, some were flexed, and others were buried in groups where both methods were used in the same grave. Occasionally a man would be laid out at full length and surrounded by the flexed bodies of several women and children. The question as to why the younger members of what appear to be a family died at the same time as the old chief has not been answered. This type of burial occurs too often to represent a family tragedy.

The bones and pottery in all deep burials were cemented and preserved by a heavy deposit of calcium carbonate that resulted from the contact of humus and sea shells in the upper layers. Many skeletons were complete in every detail, and the plates of food in the large food-offering urns still held the bones of birds, squirrels, agonti, paca, deer, marine turtles, fish, and animals that could not be identified. The teeth of tapirs, crocodiles, peccaries, mountain lions, and jaguars, as well as carved whale tusks, were found perfectly preserved.

In the whole salvaging process about two hundred bodies have been found that had not been destroyed by the bulldozer. In all this accumulation of material there is no direct or indirect evidence of European influence, so it has been concluded that the burials in this site were completed before the Spanish conquistadors overran this part of the country in 1519.

A large collection of the Venado Beach material was contributed to the Museo Nacional, where it is now on exhibit in Panama City.

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Reference

1. LOTHROP, S. K., *et al. Coclé: An Archaeological Study of Central Panama.* Part I, *Historical Background, Excavations at the Sitio Conte, Artifacts and Ornaments.* Cambridge, Mass.: Peabody Museum (1937); Part II, *Pottery of the Sitio Conte and Other Archaeological Sites*; LOTHROP, S. K. In J. H. Steward (Ed.), *Handbook of South American Indians,* Vol. 4, *The Circum-Caribbean Tribes.* Washington, D. C.: GPO (1948).

Photographs by Harry Dunn

ove: Polychrome plate of typical eagle design.

Large polychrome food-offering urn, with effigy of nkey or marmoset.

Nose rings and a variety of other ornaments carved m coral, ivory, mother-of-pearl, bone, and serpentine. hundreds of beads were carved from red and white al, and green serpentine. Through each tiny bead is recise and almost microscopic drilled hole.

Smoked-ware turtle effigy jars may have been used as lamps. One of the clay wick-holders stands in front of base.

Late Coclé culture spouted jar of polychrome design.

Effigy bird jar. Thought to have been used as an in- se burner or oil lamp.

Miscellaneous ceramics from the Venado grave site. ntral jar slightly resembles an English Toby jug.

WEEDS, INSECTS, PLANT DISEASES, AND DUST STORMS

WEEDS, insects that breed on them, plant diseases spread by the insects, and dust storms are diverse consequences that develop from a common source. Deterioration of the native plant cover begins the sequence. This opens the way for weeds, which in turn serve as favorable hosts for the insect pests, which may be directly destructive or may act as carriers of disease-causing viruses. When weeds become abundant, insects may reach plague proportions. Along with this come other effects of deteriorated plant cover, particularly the erosion of soil by wind and water. Eventually, when the plant cover is gone and the soil is left unprotected, there are dust storms.

A broad view of a particular series of difficulties drawn from actual experience in the Western states, mainly Idaho and California, is presented here. The details have been given elsewhere. At the moment we are concerned with the over-all aspects, and the relation and sequence of events. The general situation can perhaps be better visualized if it is symbolized as a plant rooted in misuse of the land—a man-created monstrosity (Fig. 1). An unstable weedy plant cover arises from the deterioration of the original stable plant cover, and this in turn springs from misuse of the land.

Viewed in another way, the problem may be seen as a succession of events occurring on the land over a period of years (Fig. 2). The most common sequence is represented by the central line of Figure 2 and can be briefly written as: shrub and grass, weeds, insects, disease. The less common, extreme effects of deterioration are shown at the top, summarized as: shrub and grass, weeds, bare ground, dust storms, and gullies. What can be done is indicated at the bottom and can be written: shrub and grass, summer annuals, winter annuals, perennial grasses, shrub and grass. Or, if plantings are made, then the order becomes: shrub and grass, weeds, planted perennial grasses.

Before being disturbed by man, the semiarid regions of the western United States had a stable plant cover of perennial grasses or grasses and shrubs. This cover may quickly deteriorate as a result of fire or be destroyed by plowing. Such changes are readily recognized. However, the cover may deteriorate over a long period of years through a combination of effects, such as overgrazing by livestock and the destruction caused by rodents. Here the changes may be so slow that they are not easily recognized or understood. When deterioration has progressed to a point where many sizable soil spaces are laid bare, these unoccupied or poorly occupied spaces offer favorable opportunities for weeds to grow. It is as if a seedbed had been prepared for the benefit of the weeds, which then reproduce at an excessive rate. Great quantities of seed are spread over all surrounding unoccupied spaces by means of natural agencies such as wind and water, or they are transported long distances through man's activities—in seed grain, in hay, and by domestic animals. The weeds are principally Old World species, which through the centuries have been selected by man's cultivation of the land or by his use of land for grazing so that they can flourish under conditions where most native species decline or are entirely eliminated.

With the weeds come the insects that thrive on them. Some of these, such as the beet leaf hopper, become crop pests. This insect breeds mainly on annual plants and requires a sequence of these as hosts to carry it through the year. In the summer some breeding takes place on sugar beets and weeds in cultivated land, but the greatest numbers are bred on Russian thistle growing on abandoned or overgrazed lands. In the fall the insect moves to the winter and spring hosts, such as mustards, desert plantain, and filaree, which are found chiefly on grazing lands. Again, in the spring, swarms of the insects move to Russian thistle, to other summer annuals, or to cultivated crops (Fig. 2).

As it moves the leaf hopper carries the virus that causes curly-top disease from the weed hosts, the

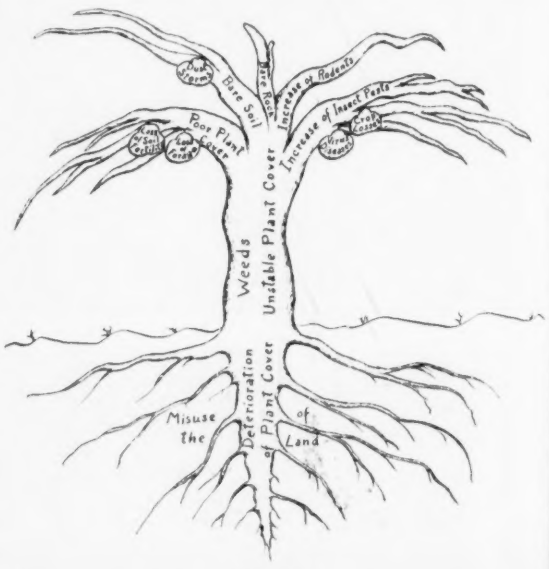

FIGURE 1.

BUNCH GRASS
SHRUB AND GRASS
DEPLETED PLANT COVER
DETERIORATION
GULLIES
DUST STORMS
IF FURTHER DETERIORATION
WEEDS
SUMMER ANNUALS
WINTER ANNUALS
BEET LEAFHOPPER
INSECTS
BEETS
(BEANS, TOMATOES, MELONS, ETC.)
DISEASE
IF ADEQUATE PROTECTION
BY PLANTINGS
BY NATURAL REPLACEMENT
PERENNIAL GRASSES
ANNUAL GRASSES
BUNCH GRASS
SHRUB AND GRASS

FIGURE 2.

overwintering reservoir for the virus, to crop plants such as sugar beets, tomatoes, beans, flax, cantaloupes, and many others. When weed hosts are abundant and other conditions are favorable, the numbers of leaf hoppers become enormous, curly top is widespread, and crop losses are heavy.

After the weeds have come to occupy the ground there may be recurring disturbances such as destruction and thinning of the stands by overgrazing. Bare patches of soil will then appear and enlarge. If at this stage there are dry years and high winds, the combination of unprotected soil, loosened soil where the crust has been broken by trampling, and sweeping winds will lay bare still larger expanses. The cutting action of the wind-blown particles destroys many young plants, and so the process continues. In one or two seasons large areas, previously with a fair cover of annual weeds, are reduced to wind-swept wastes. Soon the coarser soil particles pile up in drifts at the first obstacles in the path of the wind, and the finer particles fill the air with dust.

One other effect should be mentioned here. Man has made vast acreages favorable not only for the excessive reproduction and spread of weeds and insects but also for the existence of certain small rodents which, like weeds, reproduce and spread at excessive rates. Man not only offers large acreages of food supplies not previously available for rodents such as jack rabbits, gophers, ground squirrels, and meadow mice, but also kills off predators such as eagles, hawks, owls, snakes, coyotes, bobcats, and badgers that naturally prey on the small animals and keep their numbers in check. At times when other factors also are favorable for an increase in rodent numbers, some species may reach plague proportions. The occurrence of high numbers of rodents in dry years is especially pertinent, since these animals, unlike domestic animals, live in the area the year around. If grazing by livestock greatly depletes the plant cover, then the land will be stripped of the remaining vegetation before the rodents move or starve.

A remedial measure that strikes at all four major ill effects of plant cover deterioration—loss of forage, injury to crops, damage to soil, and dust storms—is improvement of the plant cover and replacement of annual weeds by desirable plants. The method has received extensive study, and its effectiveness has in some instances been demonstrated even though the action involved may have been prompted by other purposes. Good farming practices have reduced the acreage of weed hosts such as Russian thistle. Similarly, good range management practices to improve forage yields on uncultivated grazing lands have resulted in reduction of weed host acreages.

Good farming and range management practices are especially needed for lands of comparatively low value. Lands poorly farmed or those only intermittently brought under cultivation are sources of trouble. Such poorly farmed or temporarily abandoned and fallow lands are quickly infested with Russian thistle, mustards, or other weed hosts. The grazing lands of principal concern here are the low-lying, semidesert lands near the irrigated districts. Their grazing values are low as compared to those of the near-by hills or the higher mountain valleys, where more precipitation makes for better growth and a greater forage supply. The care given land of low value is correspondingly less than that given to land of higher grazing value. Yet much more care is needed to maintain a plant cover on land where the rainfall is low. Even though the land is of low grazing value, it is nevertheless used to a large extent to fill the need for fall, winter, and spring grazing when land in higher locations is not usable because of snow and cold.

Preventive methods are the most effective in dealing with weedy acreages. Burning, ill-advised plowing, and excessive grazing—practices that lay bare the soil for weeds to grow—should be avoided. Some lands have been plowed and then abandoned, and some have been repeatedly burned over. Most weed host areas have been overgrazed at some time or another. Overgrazing usually occurs during a series of dry years, and it is then that damage to the plant cover is greatest. A dry cycle is a crucial period for the semidesert lands, especially if small-animal pest species are abundant.

Once bare soil and weed hosts appear, there are two ways of bringing about a good plant cover—reseeding and natural replacement—which can be used to supplement each other. Each is suitable for certain conditions. Reseeding of bare or weedy ground with perennial grasses adapted to the particular locality can be used to best advantage on good soil and where the seeding can be done with machinery.

Natural replacement involves giving the land a rest from use by livestock and, if rodent numbers are high, reducing them so as to permit the plant cover to develop to a satisfactory point. With sufficient protection from damage by animals and fire, the method of natural replacement of weed hosts by other plants is very effective. Russian thistle, a host which during the fall produces the bulk of the overwintering population of leaf hoppers, can be effectively suppressed by other plants in two or

three years. The first plants that replace it may also be host plants, but they are winter hosts. Unless Russian thistle is also present in the area to supply leaf hoppers for the winter breeding grounds, the insect cannot complete its annual cycle. Moreover, the stands of winter hosts will contain annual grasses which, under continued protection, soon produce a dense stand unsuitable for leafhopper breeding, even though host plants are still present.

Under proper conditions this natural replacement of weed hosts is the quickest solution. It assumes that at the beginning there is at least a sparse cover of Russian thistle, for, if the land is bare and wind erosion has set in on a large scale, then the first problem is one of holding the soil, and replacement cannot begin until there is at least a sparse protective cover of plants.

As far as the reduction of Russian thistle is concerned, the natural replacement of weed hosts by a cover in which annual grasses predominate is not only a quick but also an effective solution. The annual-grass cover is not a permanent solution, however, because of its comparative instability. The cover is highly inflammable after the hot dry weather sets in. If after burning there is heavy grazing of the new growth, bare spots appear and weed hosts again take over. Or, if immediately after burning, high, drying winds set in, the area may be swept bare of all seed and of topsoil as well. An area may be reduced to bare soil in dry years, even without burning, if it is heavily grazed and rodent numbers are high. In dry years the patches of dense growth are short, and they dry prematurely. The intervening sparser stands, which stay green longer and which contain the plants that will furnish the seed supply for the following year, are cut off by rodents or by the grazing of livestock. Thus by one or the other of these processes the bulk of the seed supply for the next season is destroyed. The soil crust is broken by the hoofs of animals, and conditions are right for erosion and dust storms to begin. Deterioration may be rapid, in a single season, or it may be slow, covering several seasons. In a series of dry years it is most rapid and intense.

All the lands with which we are concerned here originally had a cover of perennial grasses or shrubs or a combination of the two. A development of the cover toward one or another of these is the final solution. There will need to be adequate protection until the stand is sufficiently established, whether it be one of native species or of plantings of introduced species. Once a good cover is established, proper range management will be needed if the cover is to be maintained. Reseeding of an area can shorten the time in which perennials can be established, but it will require a greater expenditure of effort and funds. Some knowledge on reseeding, as to species, machinery, time of planting, etc., has been accumulated by the U. S. Forest Service, the U. S. Soil Conservation Service, and by state agencies. By far the greater part of this information applies, however, to lands with more favorable conditions of growth than those discussed in this paper.

The natural replacement of weed hosts by nonhosts is simply the process of change known familiarly as plant succession. Such replacement of weed hosts takes place as persistently as growth takes place in the individual plant. In both cases, suitable conditions are necessary, and direct destruction puts an end to growth. Just as there are conditions necessary for optimum growth in the individual plant, so there are conditions necessary for an optimum replacement, and these can be determined and put into effect. There are certain conditions that make for growth and others that retard or prevent it. Likewise, there are conditions that tend to build up a group of plants and so favor replacement and improvement, whereas other conditions are destructive and bring on deterioration of the cover. The processes that go into building up a cover go on side by side with the processes of deterioration, on the same kind of soil and through the same series of years, regardless of the weather. Thus, the development of a plant cover from the initial weed host stand to the cover of annual grasses takes place on an area protected from harmful destruction of plants, whereas on an adjacent area where excessive destruction occurs there is a breaking down of good plant cover to a poor one or to bare soil. This process has been repeatedly demonstrated.

It is a mistake to think that all the factors involved are fully known or that they are altogether unknown. Certainly the essentials are now sufficiently well known to be applied to the development of a good cover. Where present information is not sufficient, no time should be lost in setting up proper experiments to fill in the needed information.

What is the outlook? The eventual solution lies not in lopping off a branch at a time from the baneful plant (Fig. 1) but in going at the root of the trouble by taking care of the troublesome areas where plant cover has been depleted. In some places this can be done by reseeding with suitable forage grasses; in others it will mean giving the land a rest from grazing and so permitting replacement control.

What about costs? Is the cost of replacement

control prohibitive? How much is our present attitude costing us in crop losses, in loss of forage, loss of soil fertility; work stoppage, and damage to health and property because of dust storms; road maintenance expense because of drifting soil and floods, silting up of water reservoirs? The general situation urgently demands prompt and continuing application of replacement control to help restore order in man's relation to the land. The available evidence demonstrates that benefits will promptly appear and that they will increase in subsequent years.

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NUTRITION UNDER THE CHINESE COMMUNIST GOVERNMENT

CHINA has always intrigued nutritionists because it is a large area where the food supply involves relatively simple factors: agricultural production and population pressure. The equilibrium between the two is as yet not seriously disturbed by the industrialization factor. The Communist regime, with its new theories of national economy and its plans for social and agricultural reform must face the task of effectively feeding a large population. Most of China's food habits are the result of centuries-long blind experimentation, but natural tendencies are now being replaced by totalitarian laws and regulations.

The first action of the new regime when it came into power in 1949 was to lower the standard of living, not only in respect to food, but also in respect to clothing and manner of life. This was not a gradual development; it was immediate, brought about in part by decree, but carried into effect by an overwhelming wave of patriotic feeling that made it unbecoming for anyone to be found eating food better than that available to laborers and farmers. Few could withstand being accused of being bourgeois. Students in the schools and colleges promptly spurned wheat bread and ate instead—with apparent gusto—millet bread, millet–maize–soybean mush, kaoliang, and other coarse grain combinations that have been characteristic of north China's rural diets. Millet, the most popular of these, became overnight one of the symbols of the revolution.

The dietary of the Chinese people has been the subject of considerable study.[1] It is essentially vegetarian, with approximately 90 per cent of the calorie intake in the form of cereals; in south China the cereal is rice, in north China, wheat, millet, maize, and kaoliang. The amount of meat or animal food is in general very small, and only about 5 per cent of the protein intake is animal protein. Comment has already been made on the protein factor.[2] The amount of milk and milk products consumed is practically nil. Exceptions to this type of vegetarian diet are to be found in metropolitan areas; the above figures more correctly represent the rural diet. (It must be kept in mind, however, that the people of China are 90–95 per cent rural both in habits and in temperament.) The average intake has been estimated at 2,200–2,400 calories per capita per day.

The lowered standard of living effected by the new government represents not only a decrease in quality of food consumed, but also a distinct lowering of calorie intake. The government decided that the new China must be self-supporting; food imports from abroad were to stop. This meant less food for all, and it was announced that each individual would have to eat less to carry through this phase of the nation's independence. During the past few decades, China has annually imported from 2 to 5 per cent of her cereals (wheat flour and rice). This amount is not negligible in a country where the margin of safety, as in China, is small. In actual fact, even after imports ceased, much of the population was unaware of the restricted intake. This might be explained by the fact that the shift to coarser foods would compensate in bulk for the loss in calories.

It is still too early to write with authority on the nutritive failures that may result from the curtailments in quality and quantity of the food supply. An increased number of breakdowns from tuberculosis has been reported among students and party workers, and this is popularly attributed to the lowered nutritive value of the diet, coupled with the more strenuous work and study schedules now in favor. Breakdowns from tuberculosis, always philosophically regarded in the past, are now looked upon as one type of martyrdom for the cause. The government insists that a period of re-

stricted food supply is a temporary phase, which will last only until the nation has effected substantial improvements in crop production.

When the modern Communist armies appeared on the scene in China, it was noted that along with the question of morale special attention had been given to the army ration. Provision was made for a minimum amount of green vegetables (too often lacking in the military ration), and a small amount of meat was prescribed, admittedly an amount above and beyond that available to the average civilian. At the same time, uniform rations were prescribed for government employees, for whom food is provided as a part of the salary. These government rations have received wide publicity. Three levels are specified: The first-class diet, for the small group of high-ranking government officials and others engaged in strenuous intellectual work, contains wheat bread, or rice, a variety of vegetables, and a liberal allowance of meat. The second-class diet, for office workers and lesser officials, provides less meat, and a smaller variety of vegetables, but stresses the importance of soybean curd and similar protein foods. The third-class diet, for the large mass of laborers and unskilled employees, consists mainly of millet, maize, or one of the mixed cereals, with some added vegetables. The importance of all this is not so much in the particular food items specified, but in the fact that a government is undertaking to prescribe a national dietary. Under the Communist regime an increasing proportion of the citizenry becomes government-employed, and the tendency generally is to follow government mandate.

The most far-reaching action taken by the Chinese Peoples' Republic in the realm of nutrition is that which fixed the extraction rate for the milling of wheat. The government ruling now sets 81 per cent as the minimum amount of extraction permissible for wheat flour. The regulation was promulgated about a year ago after prolonged discussion and consultation with nutritionists, and the mandate was accompanied by a vigorous radio campaign explaining the nutritional advantages of the new flour. For several weeks the figure "81" was a slogan on everyone's tongue, and the new flour was accepted as another symbol of the Communist revolution. Recent reports from north China indicate general satisfaction with the new flour; the consuming public is given to understand that more people are now able to share the advantages of wheat flour and at a lower price. The use of wheat flour had previously been the mark of the well-to-do. When I left Peking a few months ago no official action had yet been taken regulating the degree of polishing to be permitted with rice.

Millet (*Setaria italica*), as noted above, is the cereal that now occupies the center of the stage in north China. The government in Peking has not only focused attention on millet as a food and as an agricultural product, but is also using it as a currency standard. Salaries in Peking are fixed in terms of millet; a senior university professor may receive a salary of 1,200 half-kilos of millet per month. One of the universities in the capital has just announced tuition fees at 100 half-kilos of millet per term. Millet is used as a food material in Africa, India, Germany, and Italy, as well as in China, but it is not so well known in the United States, nor has it been studied so extensively as rice, wheat, and maize. The biological value of its protein is low (54–57); its protein efficiency (experiments on rats) is also low (0.9–1.4). Values reported for the digestibility of the protein vary from 36 to 74, depending on the method of preparation. Peking analyses indicate a thiamin content of about 6 μg/g, but millet is deficient in most of the other vitamins. Data in the literature indicate that improved growth results when its protein is supplemented with that from other cereals. Analyses of millet protein invariably show a low lysine content, with low values also for tryptophane and methionine. Recent studies at the Peking Union Medical College[3] show that the protein efficiency (rats) is sharply increased by additions of lysine to a basal millet diet. Supplementing with tryptophane and methionine showed no such increase. It would appear, therefore, that the successful use of millet as the principal item of food in a vegetarian dietary rests upon the discovery of a convenient and economical lysine-containing food as supplement. A decided rise in protein efficiency is invariably shown when millet is supplemented with meat.

The new Chinese government has announced ambitious plans in the field of public health. The Ministry of Health is reported to be more adequately supplied with funds than any of the other civilian services. It is not surprising, therefore, to find that the National Nutrition Research Institute is being expanded and that new projects are being undertaken. Systematic studies on vitamins in Chinese food are in progress, as are studies on more effective ways of utilizing millet as food. The low carotene content of the Chinese sweet potato (5–8 ppm) causes much concern, for throughout the country the sweet potato is an important item of food; this is especially so in the north China area, where serious vitamin A deficiency threatens. A movement is on foot to introduce the Puerto Rico

sweet potato (carotene content, 170 ppm). Soybean curd and soybean milk are being re-emphasized. At the same time the government is stressing the importance of increased agricultural production and improved seed selection. The present authorities insist that increased crop yields are possible and that they will solve the immediate problem of China's food supply.

Food economists have stressed the factor of population pressure in all considerations of food supply. So far, the new government has made no pronouncement regarding the curbing of population increase. There is no doubt, however, that the arable land available for supporting China's present population is limited and does not now adequately provide either for increase of population or for increased production of animal food. It is still to be determined how far seed selection, improved crop yields, and the cultivation of arid areas can increase the food supply and to what extent industrialization will ultimately assure food imports. There are those who feel that the new government, skilled in propaganda, and with a tendency to regulate, may well consider action in the way of limiting population growth.

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A PINEAPPLE LANDSCAPE IN MINDANAO*

TWO or three decades ago an eminent foreign geographer traveling in central Illinois observed what he called a "maize landscape." By comparison Del Monte, Bukidnon, in northern Mindanao, may be termed a "pineapple landscape" (Fig. 1).

The Philippine Packing Corporation, a subsidiary of the California Packing Corporation, has pioneered commercial pineapple culture in the Philippines. From an exploratory and truly experimental beginning in the early twenties the operation has expanded into a $9,500,000 investment. In total extent, Del Monte measures close to 25,000 acres of government-owned land, of which the company now has 15,000 acres under lease and had, in 1950, more than 11,000 acres planted to pineapple. At 11,000–14,000 plants per acre, that is enough to keep the packing plant in operation eleven months out of the year. Possibly the extent of the plantation can best be visualized if one considers that it takes forty-five minutes, by automobile over good unpaved roads, to cross the pineapple-growing areas in their largest dimension, which is roughly northwest to southeast. At points on this route there is pineapple from horizon to horizon.

The site of the plantation is near the northern edge of the Bukidnon Plateau some ten airline miles from the shores of Macajlar Bay (Fig. 1). This intermontane upland is a broad, grassy tableland of sedimentary rocks, cut by sharp ravines and canyons. It lies between the mountains of eastern Mindanao and a central mountain area, both trending in a general north-south direction. Its 6,000 square miles of terrain have an average elevation of about 3,000 feet, topped by two local mountain areas (Katatungan and Katanglad Mountains) that tower to 7,500 and 7,800 feet, respectively. The northern edge of the upland is a rugged escarpment separated from the bay by a narrow coastal plain, in most places less than a mile and locally less than one-fourth mile wide. The northern part of the upland is somewhat lower than the central and southern portions, and the Del Monte settlement has an elevation of only about 1,700 feet. The altitude of the plantation ranges from 1,700 to 2,300 feet.

The plantation is, in reality, a series of noncontiguous leases along the sides of the little Agusan Canyon† and certain lesser canyons and ravines. The nonleased areas are composed of brushy or cogon grass wasteland within or along the sides of the canyons, or flatter areas that are too small or otherwise unsuited for effective use in mechanized plantation agriculture. The latter is planted principally to corn and rice. The flat-topped upland has a lateritic, dark, red-brown clay or clay loam soil. It is granular, well drained, and more fertile than most residual soils of the tropics. Even so, 400–500 kilograms of fertilizer per hectare are necessary to obtain desirable yields. The clay loam grades into a red or red-brown subsoil with basaltic pebbles and boulders, which in turn is underlain by volcanic lavas as much as 15 feet below the surface. The soil

* The research upon which this paper is based was made possible by grants from the United States Educational Foundation in the Philippines (Fulbright program) and the University of Illinois Research Board.

† Not to be confused with the larger Agusan River in the province of the same name to the east of Bukidnon.

dries very rapidly after a tropical rain, so rapidly that it is usually possible to plow or cultivate any morning even though there has been an inch or two of rain the preceding afternoon or early evening.

Climatically speaking, the site of Del Monte is near ideal for pineapple culture. It is outside typhoon paths, hence does not suffer from violent winds. In fact, the climate is almost nonseasonal, with mean monthly temperatures ranging from 71° to 74° F. The city of Cagayan de Oro, on the coastal plain, has an average annual rainfall of 64 inches, and precipitation at the plantation headquarters averages 108 inches, most of it in the form of heavy, late-afternoon or early-evening tropical thunderstorms (Fig. 2). Probably no other place in the Philippines has precipitation that is more regular in type and time of occurrence. Since this is an upland area with convectional precipitation, runoff is rapid, and erosion control is necessary. Heavy tractors and equipment are used to construct broad, shallow waterways with a low gradient. The ridges are kept low so that planting and cultivation, as well as roads, are not interrupted by them.

Bukidnon is not densely populated. Most of the workers have migrated from the Visayan Islands, principally Bohol and Cebu. Wages are not high. Fieldworkers and laborers in the packing plant receive less than ₱3.00 ($1.50) per day.‡ Skilled labor may get twice that amount. Since labor is not costly there is little mechanization on the plantation. Tractors with appropriate equipment are used

‡ Wages of factory workers have no doubt been increased to at least ₱3.00, as required by the minimum wage law passed by the Philippine government in April 1951. Most fieldworkers receive more than the minimum required for agricultural workers, for plantation labor is apportioned on the *pakio* system—the more work a man does in eight hours, the more money he receives.

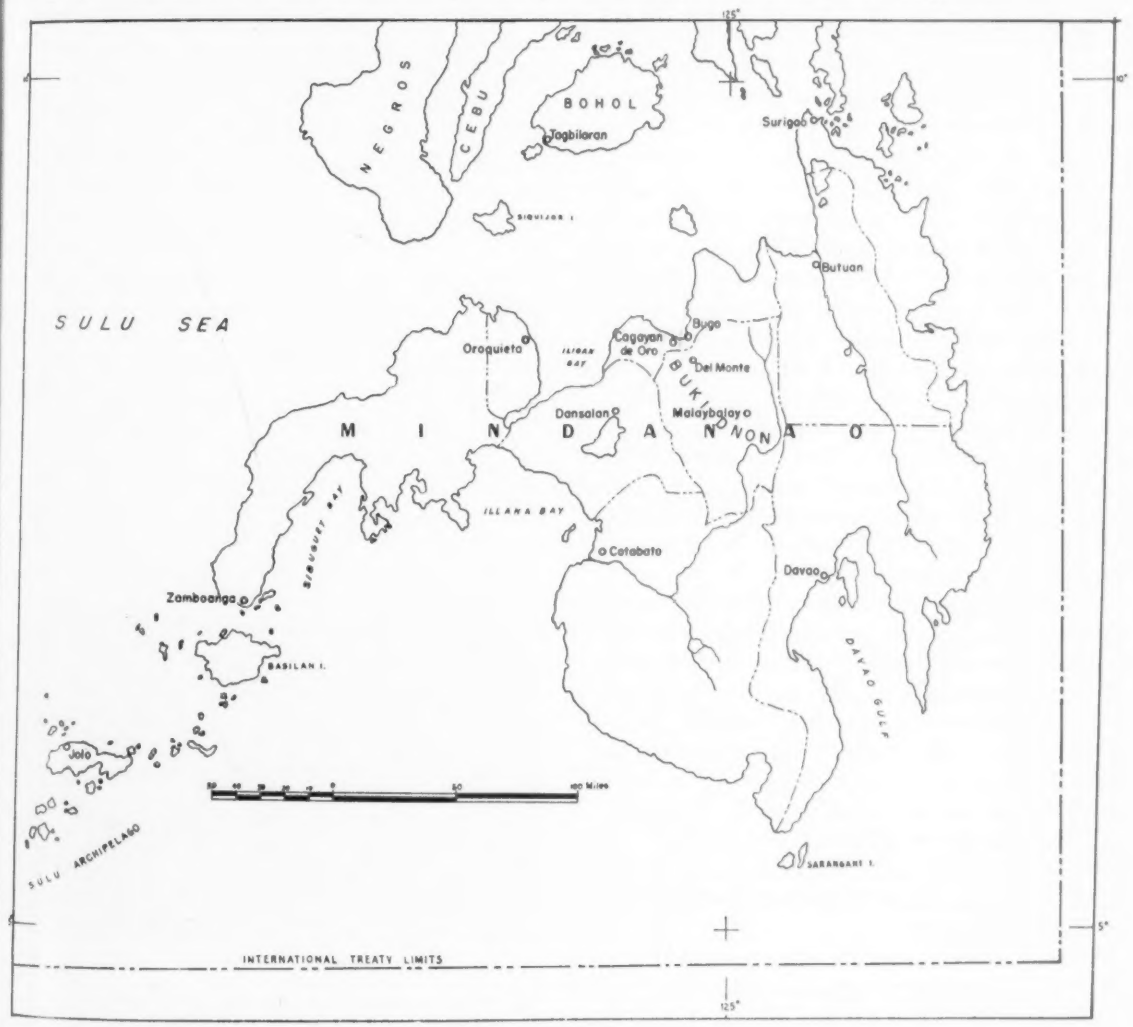

Fig. 1. Mindanao.

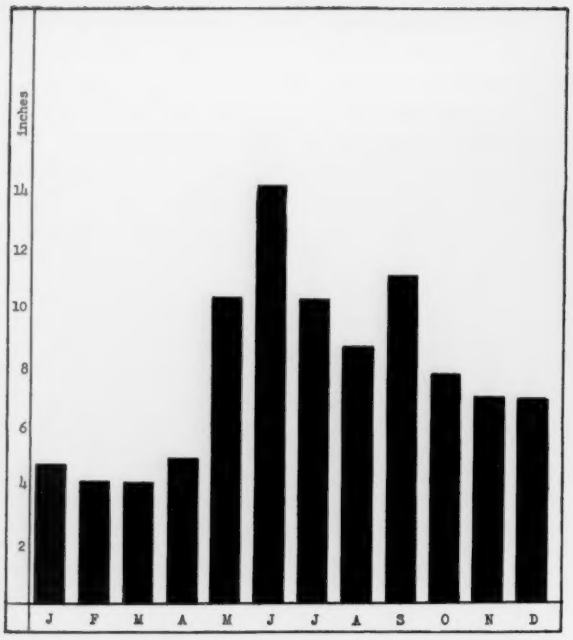

FIG. 2. Average monthly precipitation at Del Monte. Record is for thirteen years, 1929–38 and 1947–50.

to chop pineapple stumps, plow and pulverize the soil, and prepare drainage lines ahead of the planting crew. Planting, fertilization, and harvest are hand operations (Figs. 3, 4), and a good worker can set 7,000 plants in an eight-hour day. Some carabaos are used, but cultivation is principally with "Brahma bullock," a hybrid offspring of an Indian Brahma bull and a native cow. The field-worker begins his day at 5:30 A.M. and finishes at 2:00 P.M., a response to higher afternoon temperatures and late-afternoon rains. He lives in a worker's barrio, conveniently situated on that part of the plantation where he customarily works, and walks to the field at daylight. He is usually home before the start of the daily rains.

The staff men and their families live in prefabricated homes of pleasant design. There is a clubhouse, a nine-hole golf course, and large areas of well-kept green lawn. So extensive is the grassy area that it is used as a landing strip, and Philippine Airlines makes Del Monte a flag-stop on its Cebu–Davao run. Planes taxi up to the clubhouse, where a guest cottage provides accommodations for visitors. This air of luxury and comfort has given Del Monte a wide local reputation, but it is provided more by nature than by the expenditure of huge sums of money.

Filipino laborers and lesser executives are provided with rent-free quarters and free medical and dental services, sick benefits, vacations with pay, free movies, and a Christmas bonus. Labor agitators

FIG. 3. Planting pineapple. After the plant material has been scattered in the field (lower right), the worker sets it in the ground along a wire stretched across the field to insure uniformly spaced rows.

have not prospered, for labor gets better treatment here than in most other places in the Philippines.

Philippine Packing operates the only pineapple cannery in the Philippines. It has grown into a $10,000,000 export industry, almost all the exports going to the United States. It provides employment for 3,500 Filipinos, slightly more than 25 per cent of that number in the cannery, the remainder on the plantation. The cannery at Bugo, on a sandy strip of coastal plain fifteen highway miles from the plantation and about the same distance from Cagayan de Oro, is a year-round operation except for a short shutdown for the repair and reconditioning of equipment.

By controlling the type of plant stock used and the time of setting it into the ground, and by forcing the crop if and when necessary, a uniform flow of fruit to the cannery is possible, and yet none is in need of processing during the period the cannery equipment is being overhauled and reconditioned. In setting a new field, the plantation manager may

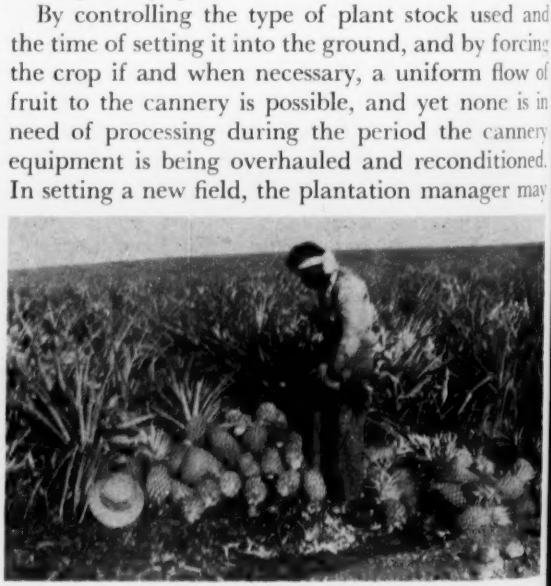

FIG. 4. Harvesting pineapple. The fruit has been cut from the stock and carried to the end of the field, where the worker tops and trims it, after which it will be loaded into a truck for transportation to the cannery. Note absence of vegetation other than pineapple.

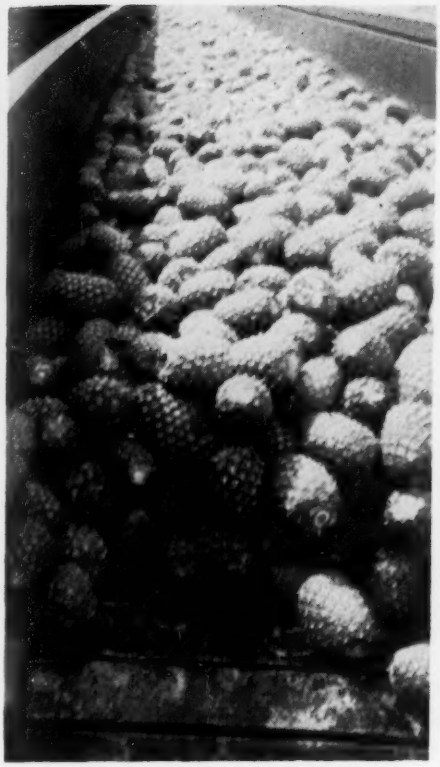

FIG. 5. Trimmed and washed pineapples on mechanical sorting table at the cannery.

utilize (1) tops, which reach maturity in slightly less than two years, (2) suckers, which yield fruit in twelve to fourteen months, or (3) shoots, which mature at a period intermediate between the other two types of plant. Fruit can be forced to mature earlier than normal by application of ethylene to the heart of the growing plant. This treatment stops the growth of new leaves and causes the "redbud" (blossom and young fruit) to appear more rapidly than otherwise. Since the pineapple is a perennial,

FIG. 6. Trucks of pineapples in the cannery yard at Bugo. Loaded truck is backed into the galvanized-iron shed and its bed tilted gradually so that the fruit rolls onto the washing and sorting tables immediately to the right.

ratoon crops are possible, but the size of the fruit drops off markedly with each successive crop, so as a rule only the second crop is harvested before the field is replanted.

A commercial pineapple industry in Bukidnon has several advantages and few disadvantages as compared with a similar installation in Hawaii. The Bukidnon climate is better, for there is no dry season. Planting and harvesting operations can be spaced more uniformly over the year for better utilization of labor and equipment. The fruit is larger, apparently a climatic response also (Figs. 5, 6). Philippine labor is much cheaper than labor in Hawaii, and with proper training and experience can fill all except the administrative and a few key supervisory positions.§ Transportation is not expensive, for it is a downgrade haul from field to cannery (Fig. 6); the corporation has its own pier, so ocean vessels load and unload only a few yards from the processing plant. The Philippine industry has three disadvantages. Because of the moister climate, greater expenditures for pest and disease control are necessary. Second, the Philippine cannery is farther from its major market and the source of its most important raw material (other than the fruit), namely, tin plate. Finally, it is inconvenienced, and at some time in the future may be handicapped, by the import-control program of the Philippine Republic. Thus far, there has been no stoppage of operations and associated loss of fruit, but the plant has been operating more or less on a hand-to-mouth basis while its monthly and quarterly quota allocations of tin plate are acted upon by federal agencies (1950 and early 1951).

There has been no recent attempt to expand operations to products other than the various canned pineapple products. (California Packing originally came to the Philippines to can tuna, and the first packing plant was built for that purpose. This early operation was unsuccessful, and the purely secondary and experimental interest—pineapples—proved the profitable venture.) It would appear that the fresh-pineapple market of the larger cities of the Philippines might be profitable. There are normally no fresh pineapples on the Manila market except for a few months, and those are mostly fruits of native stock, both smaller and less sweet than the more scientifically grown Bukidnon product.

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§ There are only three Americans on the plantation and not more than a dozen in the combined office and cannery force at Bugo.

BOOK REVIEWS

A CITIZEN'S GUIDE

American Resources: Their Management and Conservation. J. R. Whitaker and Edward Ackerman. x + 497 pp. Illus. $6.75. Harcourt, Brace, New York. 1951.

JACKET blurbs are not conspicuous for their restraint in praise of a book's contents or significance, but in this case you can, in the reviewer's opinion, go all the way with the statement that "*American Resources* goes farther than any other published work in taking account of the social and economic and political setting of conservation problems. . . ."

The authors are geographers of note, and their presentation reflects some of the best characteristics of the discipline. Adequate data for their purposes are to be found in context, and they go far beyond the "facts" in both analysis and synthesis. If you want some of the most pertinent information about cultivable land, grasslands and forest lands, water resources, minerals, and recreation (including fish and wildlife), you will find it in the chapters under the five sections of the body of the book with the above headings. But you find much more than data, however important; you find interrelations among resource problems, and you find integration in the treatment. This can be illustrated by a table on conservation objectives and measures that has the following organization: social objective (human welfare); resource objective (maintenance of quantity and quality); direct conservation measures (preservation, restoration, beneficiation, efficient production and use, re-use, substitution, inventory, and appraisal); social measures to promote conservation (public aids, legal controls, public school, college, and mass education).

The authors are not interested in technology, and their over-all concern is not with any single resource but, as they say, "with the maintenance of the total resource base of the American people." They are, then, inevitably involved in human problems, although their approach is through analyses that are mainly national and topical. Thus you will find, to take water resource as an example, a consideration of water uses (potable supplies, industrial uses, irrigation and other agricultural uses, navigation, power, fish, and wildlife); water supplies (surface waters, aquifers, artesian); water damage and water-use impairment (flood damage, salt, sewage, and industrial pollution, erosion damage); water management; and multiple use. There are considerations of private and public interest, of regional, interstate, and national interest. There are considerations of watershed problems, of plans, and of projects, such as the TVA and other authorities. The treatment of the principal resources is more than adequate, although it does not attain the publisher's claim that it is "definitive."

The high point of the book, and its greatest distinction and usefulness, I believe, are in the concluding chapter, entitled An American Citizen's Guide to Conservational Resource Management. Here you find social philosophy and perspective, and here the reader is led to the crux of many matters—and the chances are that the reader needs this guidance, whether he be student, professional conservationist in some specialty, or layman—and, best of all, he is not only confronted with situations and problems, but with realistic suggestions for the individual citizen's role. Without minimizing our misuse of the land and other resources, and the great needs that remain for adequate resource-use policies and practices, the book is not "scare writing." It leaves one with a good taste in the mouth; with a sense that a resource ethic can be developed; with a feeling that, although Herculean tasks lie ahead, intelligence, resourcefulness, and democratic cooperation give us a fighting chance and that we can put our hearts into the struggle.

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MODERN SCIENCE FOR THE LAYMAN

The New Physics. Sir C. V. Raman. 144 pp. $3.75. Philosophical Library, New York. 1951.

THE contents of this volume were originally delivered as a series of radio talks to the Indian public. They are therefore "intended for the layman." The author was the recipient of the Nobel prize in physics in 1930 for his discovery of the effect that bears his name, and the nineteen chapters deal in an interesting manner with different problems and observations in the field of physics.

In the first chapter Raman states that, whereas "the old physics was successful chiefly in giving what might be called a macroscopic or large-scale description of natural phenomena," the "new physics" has made it possible to interpret these phenomena in terms of atomic and subatomic units of structure. This has led to the opening up of "new territories of phenomena not contemplated by the older physics." Chemical physics is one such new field, and the synthesis of new chemical elements is another.

The second chapter, entitled Physics in the News, contains a stimulating discussion of the purpose of scientific study and research. "To the physicist," Raman declares, "falls the task of discovering the ultimate units or entities that constitute the material universe and of ascertaining the principles which govern their behaviour. This quest takes the physicist farther and farther every year, and the end is not yet in sight." A topic of interest to the physicist, but for which there is apparently no immediate practical application, is cosmic rays, which is

discussed in this chapter and also in a subsequent one.

In other chapters there are stimulating discussions of Shells; Geometry in Nature; Light and Colour in Nature; The Sensations of Light and Colour; Light and Colour in Science and Industry; Physics of the Countryside, including the soil, water, and weather; The Romance of Glass; Atmospheric Electricity; and Modern Physical Concepts about crystals, solids, and cosmic rays. The author is an enthusiastic scientific investigator and is successful in communicating his feelings to the reader. Chapters 17 and 18, entitled The Stellar Universe, contain a timely discussion of the origin of stellar energy, and in the last two chapters—The Future of Physics and The Scientific Outlook—the most impressive features are the author's predictions of what the future holds and his remarks on the origin of discoveries.

For the expert in science these talks will bring little or no new knowledge, but they are extremely valuable in demonstrating the manner in which even familiar facts may be presented to a layman in a simple and stimulating form.

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REGIONAL ECOLOGY

Mountains and Moorlands. W. H. Pearsall. i + 321 pp. Illus. 21*s*. Collins, London. 1950.

THE aim of a regional ecological study is to develop an understanding of an environment and all the creatures in it as a functioning dynamic system. The difficulty inherent in this is well indicated by the fact that the objective has seldom or never been quite accomplished. *Mountains and Moorlands,* ninth volume in "The New Naturalist Series," approaches more nearly such an accomplishment than anything that has ever come to my attention.

It is clear that this was not a task that the author set out to do as an ecological problem. It is obviously something that he has lived with, loved, and been continuously fascinated by for a long time, perhaps all his life. The depth of his familiarity with his region and the breadth of his knowledge of all aspects of it are such that they could not have been acquired in a short time. They are also proof that the old-time general naturalist is still extant, and that, preserving his omnivorous interests, he has still been able to absorb and apply the thinking and viewpoints of modern ecology.

This book treats the highland region that makes up the northwestern half of Great Britain. Written in language that any intelligent person should be able to understand, yet sacrificing nothing of depth or accuracy, it describes the geological structure of this region, its climate, soils, and vegetation. As it goes along, it develops the interrelations and interdependence of these, and the way that together they make up the habitat of the plant and animal populations that live there. The situation is complex, with mountaintop vegetation, grasslands, woodlands, moorlands, and bogs. In a penetrating discussion of the ecological history of the area the fact is brought out that most of these habitats are developmentally related; that before the advent of man the changes that took place were of a secular nature, but that human occupation of the area accelerated them, and that most of the change has been of the nature of degradation of the habitat. Erosion, leaching, and the creation of sterile, acid bogland over wide expanses have been the result.

Chapters on the animals—invertebrates, mammals, and birds—and on the animal communities, and a careful consideration of their nature and history, follow, showing that the major communities are largely man-made and that all the communities show an impoverished fauna. The final chapter considers the future of the area in terms of the possibilities of its rehabilitation as a habitat for man, with some suggestions as to the extent to which this may be carried and the means by which it may be accomplished.

Two outstanding features of the book are the extent to which the author has been able to integrate all the information at hand into a functional and understandable picture, and the way he has utilized the abundant illustrations as a necessary part of the text. Thirty-four superb black-and-white photographs and forty-six in color, as well as various line drawings and diagrams, are scattered through the text. These are made use of constantly and repeatedly to illustrate every important point discussed. Their selection shows keen judgment, for they constantly emphasize the beauty of these mountain areas and at the same time identical illustrations fit many parts of the discussion. The planners of books would do well to study the effectiveness of these illustrations carefully. And the manufacturers of books might well follow the example of the perfection of reproduction exhibited here.

The appearance of such a book is an indication both of the maturity of English ecology, in being ready to write it, and of the maturity of the English reading public in being ready to read it in sufficient numbers to make it possible to produce it so well and so cheaply.

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INDUSTRIAL STATISTICS

Technological Applications of Statistics. L. H. C. Tippett. ix + 189 pp. Illus. $3.50. Wiley, New York. 1950.

TIPPETT'S book is a great contribution to industrial statistics. The publisher's statement on the paper wrapper correctly describes its purpose—"presents the logic of the statistical methods to be employed and emphasizes their practical applications to technological problems." Tippett succeeds ably in carrying out this purpose.

As a consequence, the book is somewhat unique among books on industrial statistics, for most such books emphasize *methods* rather than the *logic* underlying them. The author is to be complimented on a logical,

mature, and (in general) readable presentation of a subject that all too often is presented in cookbook style.

Tippett's book is recommended not only to those not yet familiar with the applications of statistics to technology, but also to the growing body of workers in industrial statistics and statistical quality control for this reason: It covers a number of topics not usually treated in books on industrial statistics. For example, after describing the usual statistical quality control techniques in the first 74 pages, the author devotes Part II (110 pages) to "Investigation and Experimentation." In it, he explains how industrial experiments may be designed to yield the most reliable answers at the cheapest cost. A number of experimental designs of increasing complexity are presented, with illustrations from the cotton and steel industries. (Unfortunately, some of the illustrations are not the easiest in the world to follow—at times, I found myself enmeshed in a tangled web of "gaitings," "leas," "cops," etc.) The last chapter, Planning an Investigation, seemed especially valuable and stimulating, for it explained and illustrated some of the basic concepts that enter into the most efficient and scientific planning of experiments.

The style of the book reminds one strongly of that of R. A. Fisher, the great British statistician, as embodied in Fisher's *Statistical Methods* and *Design of Experiments*. Since the book is a "write-up" of a course of lectures given at MIT, it has a pleasant informality.

The book is not intended as a systematic textbook in the subject, and hence lacks some features that would be of value. There are no exercises, although, as the author suggests, the reader gains a great deal by working through the illustrative problems of the text. In addition, the author does not attempt to present the statistical methods in detail, but rather refers the reader to other sources.

Technological Applications of Statistics should be read by technologists, industrialists, and industrial statisticians even though it might require cutting out reading the daily paper every other day—it would be more profitable and less disturbing.

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TOWARD SOUND CONSERVATION

Forest Management. Herman H. Chapman. xix + 582 pp. Illus. (No price given.) Hildreth Press, Bristol, Conn. 1950.

RARE indeed is the person not interested in trees. Comparatively few, however, fully comprehend the complex factors of forest economy. Professor Chapman is one of those who does. This volume is a distillate of his work of nearly half a century as professional forester and teacher specializing in forest management. Its 30 integrated chapters are subdivided into 304 articles, each a pointed essay on some particular topic. Numerous tables or graphs serve to illuminate individual items.

The foundation on which the volume has been built is clearly set forth by the author in the following:

> Forestry occupies the same position in the economic chain as farming. Lumbering is parallel to mining, dealing with an exhaustible resource. To substitute forestry for mere continued exploitation of natural forest growth, to farm the forest soil, to continue the productiveness of forest areas and thus maintain the supply of wood for all needed purposes, constitutes the first great step in placing our national economy on a permanent basis. This can be effected only through intentional investment and definite organization of forestry as a business enterprise.

In the needed substitution of forestry for lumbering, it is further pointed out that "all forms of industry, in order to survive, must provide for their own continuance." Much of the remainder of this encyclopedic work is an amplification of these basic principles as they apply to sustained yields and efficient methods of forest management.

The volume is so organized that it could be used as a classroom text by forestry students. Yet it is not cluttered with pedantry; it comes directly to the issue, sometimes pungently, with general statements often exemplified by actual instances. The book could equally well serve as a reference guide to the professional forester, for frequently it contains observations that have particular application and certainly would cause the manager of any forest tract to pause on occasion for self-questioning as to whether he was handling his area in the most efficient manner.

It is not often that a work on so specialized a topic can be recommended to the layman interested in land use patterns, to anyone concerned with the management of recreational areas in forest regions, or even to the sociologist dealing with the development of stable communities associated with a major industry at one time conducted on a temporary basis. Forestry has a specialized vocabulary, with word usages peculiar to the profession, yet one of the admirable features of the present volume is that the terms as used and applied by foresters are carefully defined; thus the layman can read the text with adequate comprehension. Certainly here is a book wherein he is able to ascertain the numerous problems faced by the professional forester when he attempts to achieve sound forest management.

Those who are at all interested in forests as recreational areas will gain much from the sane approach to this topic, especially in Chapter 29. The author clearly states the desirability of the preservation of certain tracts as "wilderness areas," these to serve as examples of primeval forests. He rightly points out, however, that a too-great extension of such areas, often sponsored by overzealous sentimentalists in the name of conservation, is not conservation at all. We must face the elemental fact that an overage and decadent forest is not a healthy one; too often it is a veritable cesspool of forest tree diseases and insect pests constantly threatening to spew their spores and offspring into adjacent—even distant—healthy, still-growing timber. One wonders just how long we can afford the dubious luxury of maintaining certain of these unproductive "Typhoid Mary" areas in our forest population.

Our Canadian friends, who once thought their forests were inexhaustible, have recently discovered that, where tree harvesting is economically possible, the cutting and annual increment of the stands are approaching parity. In the United States we long ago passed this point, so that today we are cutting our forests about twice as fast as we are growing them. Continuance of such a shortsighted policy can lead only to complete bankruptcy in this, our only renewable natural resource, so vital to our present civilization. Real conservation through proper controlled harvesting, making certain that a healthy new crop of trees is coming along on schedule, is the only sensible answer to this vital problem. Chapman's *Forest Management* is a general outline of how this may be accomplished. Foresters may well argue over certain details of procedure, just as the clergy sometimes differ over the best way of conducting one's life. All will agree that an expanded practice of sustained yield is as necessary to a balanced forest economy as is the practice of the Golden Rule in everyday life.

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SPECIALIZED CHEMISTRY

Colloidal Dispersions. Earl K. Fischer. vi + 387 pp. Illus. $7.50. Wiley, New York. 1950.

THIS book is not a broad treatment of all types of colloidal dispersions, but presents, rather, a more specialized approach chiefly concerned with fundamental principles that are important in the manufacture of colloidal dispersions of solids, such as pigments, in liquids. The first five chapters, taking up about two thirds of the book, deal almost exclusively with these fundamental concepts. The remaining seven chapters give attention to the more practical aspects of dispersion, with especial attention to mechanization needed for its achievement.

The treatment of the topics is usually thorough, suggestive, and well documented. Two chapters, with a total of 110 pages, are devoted to problems concerned with size, shape, and condition of dispersed particles in dispersions of industrial interest. Almost 300 references to recent literature are included in this comprehensive discussion. Since it is one of the most nearly complete descriptions published of the disperse phase, as such, in colloidal dispersions, it is somewhat surprising to find no mention of the use of profile microscopes and interferometers in the investigation of surface roughness.

In the chapter on The Solid-Liquid Interface and Wetting, the treatment is much like that usually given in standard textbooks of colloidal chemistry. The discussion of spreading coefficients is based on the early papers by Harkins and collaborators but does not include the concepts of semi-initial and final spreading coefficients. It would seem that in industry the conditions that lead to initial spreading coefficients would be rarely encountered. Antonoff's rule is not mentioned.

Dispersions of white lead in oil have been prepared from aqueous dispersions, by displacement of the water by the oil, for over half a century. Although little has been written on the subject, outside of patent literature, nearly all commercial colors and pigments have been processed in recent years by this phase transfer, or flushing, process. Among the important factors are the interfacial energies acting on the particles. References are made to nearly 50 patents in this field, but the patented processes are not discussed in terms of interfacial energies—a fact that is not surprising to workers in this field.

Publicity has been given to industrial use of high-frequency sound waves in the production of dispersions. Ultrasonic radiation has been successful in preparation of emulsions, but in the author's experience—"the disintegrating effect of this radiation on pigments such as iron blue, carbon black and barium lithol suspended in oils, is negligible." Colloidal dispersions may result from the application of ultrasonic radiation to solids of moderate cohesion, but with "materials of high cohesion (e.g., glass, quartz, marble) colloidal suspensions are never produced."

A brief outline of mixing of low viscosity suspensions is followed by nearly 70 pages of discussion of the important details concerning the use of colloid, ball, and roll mills in the preparation of dispersions. Not much is given concerning the working of high polymers.

The volume is well written and should be of value chiefly because of the suggestions and critical evaluations of important factors pertaining to the manufacture of dispersions. The treatment is essentially descriptive rather than mathematical, but the many pertinent references to the original literature make it possible to study the original developments. The book's offerings should appeal not only to those primarily concerned with related manufacturing processes but to teachers and students who are interested in the industrial applications of fundamental colloidal principles. Such reference use is aided by 21 double-columned pages of author-subject indices.

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HISTORY AND NATURE OF THE OCEAN

The Sea Around Us. Rachel L. Carson. vii + 230 pp. Illus. $3.50. Oxford University Press, New York. 1951.

RARELY has the soul of the sea been so adequately fathomed or its thousand faces so delightfully pictured as Rachel Carson has done in her latest book, *The Sea Around Us.* The many technical divisions of oceanography have been blended in a manner that gives the reader a full appreciation of the history, nature, and cyclic functions of the ocean.

The book is divided into three main sections, the first dealing in eight chapters with various modern

phases of oceanic biology and marine geography, the second part picturing the dynamics of waves, currents, and tides, and the last three chapters discussing man and the sea about him.

Although the chapter on The Birth of an Island won for its author the 1950 George Westinghouse Science Writing Award, several other chapters are of equal, if not superior, caliber, as, for example, her treatment of marine sediments in The Long Snowfall. The normally staid story of sedimentary rocks has been presented in living fashion. The reader feels the spirit of the timeless and inexorable rain of myriads of dying planktonic lives descending from the surface ceiling of the sea to the ever-thickening sediments on the ocean floor. "It is interesting to think that even now, in our own lifetime, the flakes of a new 'snowstorm' are falling, falling, one by one, out there on the ocean floor. The billions of Globigerina are drifting down, writing their unequivocal record. . . ." As in so many of her other chapters, the author has interlaced the most recent advances in oceanography. In her descriptions of unseen life in the sea, she presents an up-to-date account of the work being done in underwater sounds. Hydrophone techniques are revealing a new world under the sea, from the froggy croaks of fish and the whistles and squeals of porpoise to the fat-frying sizzle heard from beds of snapping shrimp.

The importance of the sea to man is forcefully demonstrated in the chapters on The Global Thermostat and Wealth from the Salt Seas. An account is given of the long-range cyclic effects of tides and currents on European climate and the history of modern man. In the final chapter, The Encircling Sea, man's knowledge and legends of the mysterious sea are entertainingly presented in a historical review extending from the time of the ancient Greeks' ocean, which was an endless stream flowing around the border of the earth, to the first works of Matthew Maury and present-day sailing directions and coast pilots.

It is singularly refreshing to find a popular book on a scientific subject which can carry the reader so gently and pleasantly through the mazes of science and yet maintain such a high degree of accuracy. This is because the author is a poet and scientist.

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A FORWARD STEP

The Hebrew Impact on Western Civilization. Dagobert D. Runes, Ed. xv + 922 pp. $10.00. Philosophical Library, New York. 1950.

DIFFICULT to uproot and to demolish has been the persistent and erroneous notion that the Hebrews' only original contribution to Western civilization was made in the religious sphere. Since Christianity has borrowed the monotheistic concept and other vital tenets of doctrine from the Hebrews, the emphasis has naturally been on what the Hebrews have contributed in the religious and moral realm; consequently their sparkling contributions in other sectors of Western culture and civilization have been either overlooked or minimized.

Thus in delineating and emphasizing the brilliantly original contributions of Hebrew scholars in every phase of Western civilization—art, music, mathematics, law, medicine, sociology—Dagobert Runes and his distinguished co-authors have achieved a scholarly synthesis. Here are reviewed the accomplishments of thousands of Hebrew scholars over several millennia; here, too, are illustrated the specific ways in which these achievements have enriched and strengthened Western civilization. The book is of encyclopedic nature, treating in much detail the multifarious intellectual attainments of the Hebrews from Moses, the lawgiver of the Bible, to Einstein, the genius of relativity.

Nevertheless, although the co-authors of the book are on solid ground in disposing of harmful, stereotyped notions, they fail to explain why the accomplishments of the Hebrews in every sphere of Western civilization have been on such an impressive and grandiose scale, out of all proportion to their numbers. This failure to analyze the causes accounting for the flowering of Hebrew culture vitiates the value of the book.

Shall we accept Veblen's hypothesis that the Hebrews were able to make such strikingly original contributions in every country of migration because, as a despised minority, rather than unquestioningly accepting the customs and mores of the native population, they stubbornly persisted in seeing things from a somewhat different point of view? According to this hypothesis, since the Hebrew immigrant in many, if not most, cases was also in revolt against his own traditions, he was compelled by the inner logic of his situation, so to speak, to overcompensate, through great and original achievement, for his feelings of inferiority, rejection, and maladjustment. This assumption, however, ignores the monumental attainments of those of Hebrew faith and culture who were loyal to their ancient traditions and customs and who did not have negative feelings of maladjustment. Indeed, the vast majority of Hebrew immigrants in every land adjusted remarkably well to their environment, unless they were outrageously and mercilessly persecuted. Veblen's hypothesis therefore has heuristic value in some cases, but is not necessarily correct in the great majority.

Another hypothesis explains Hebrew intellectual achievements along the lines of the survival of the fittest. This assumes that the elements of the population weaker in mind and body were exterminated by the numerous pogroms and massacres that have decimated those of Hebrew origin through the ages. The concept of the survival of the fittest may sound plausible here, but the argument is essentially specious and unscientific. The extermination of 6,000,000 Hebrew people by the Nazis was certainly not conducted along eugenic lines, nor is there evidence to demonstrate that the survivors were strongest in mind and body.

It is not the intention of this reviewer to analyze all the explanations that have been offered in this respect. The hypotheses cited are merely two examples of what

has been done in the field. A vast amount of work remains to be done.

Despite the failings of the book on this score, it undoubtedly is a forward step in the direction of research that would be helpful in dispelling deep-rooted prejudice and bias.

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A SMALL DROP OF INK

Logic and Language. A. G. N. Flew, Ed. vii + 206 pp. $3.75. Philosophical Library, New York. 1951.
Words and their Use. Stephen Ullman. v + 108 pp. $2.75. Philosophical Library, New York. 1951.

COMPARISON of these two books prompts the reflection that study of language may lead to philosophical considerations, and that some present-day philosophers are devoting much attention to problems raised by language. It is questionable, however, whether a reader unversed in the subtleties of the English analytical approach would find the first of them easy (or profitable) reading. Its nine papers, gathered from various sources and covering a period of some twenty years, are professedly based on the principle that grammatical resemblances and differences may be logically misleading, and that "grammatically respectable sentences might be logically disreputable." Ryle conducts us through a survey of quasi-ontological, quasi-Platonic, and quasi-descriptive statements which he finds to be systematically misleading, although they are tolerated in customary usage and apparently work well enough in the situations of ordinary discourse. On the other hand, Edwards' discussion of Russell's doubts about induction is couched in terms much closer to those of ordinary thought, and does not seem to involve linguistic restatement at all. Paul's review of sense-data, again, discusses the term as a word connected with other words, but in very general terms, merely paraphrasing what "people" are supposed to have said about it, without coming to grips with the questions raised by individual thinkers. If a single method is at work here, its workings are not too easy to make out.

A much deeper level is reached by Waismann's discussion of Verifiability. It considers the "open texture" of most empirical concepts, the essential incompleteness of empirical descriptions, and the consequent failure of definitions of empirical terms to cover all possibilities, whereas in mathematics a closed definition can often be reached. Accordingly, it is unrealistic to conclude that whereas a "law cannot be strictly verified, it can be strictly confuted," and must be abandoned on a single counterobservation. It is better to say that "the known relations of logic can only hold between statements of a homogeneous domain; or that the deductive nexus never extends beyond the limits of such a domain." This means that the statements of our language form distinct strata, in each one of which there is a linkage of logical relations; but when two strata make contact various problems, philosophical and other, arise. Consequently, no natural language can be perfectly formalized, and we have to do the best we can with its unavoidable incompleteness. The elements of our interpretations of reality are, without our knowing it, already present in language, which "contributes to the formation and participates in the constitution of a fact;" and a scientific theory "is essentially a construction which more or less reflects our own activity." These are some of the high points of a very stimulating contribution, which contrasts markedly with the other papers. They seem mostly content to take "language" as no more than present-day English usage, and "logic" as mainly the outcome of linguistic analysis, not as positive "thought about things."

Our second book, on the other hand, is mainly a survey of certain aspects of language, rather in the manner of a guidebook, with indications of places where some of the topics have been more fully treated. The supporting examples, though well chosen, are mostly from the general stock of such things, and the resulting impression is quiet rather than stimulating. In the final section, however, more fundamental aspects of the adequacy of language are touched on, including the "linguistic field" theory, the problems of translation and syntactic structure, and the growth of semantics, with a glance at Basic English; but the treatment is too brief to be more than an incentive to further reading. A two-page bibliography of representative works is given, but a reader who had begun with one of them might find that he had been led into the subject quite as quickly, and more substantially. Anyone who ventures into present-day linguistics must be prepared to make his way out by hard thinking; he is not likely to find logic and language easily and quickly reconciled.

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BRIEFLY REVIEWED

Forest Products. Nelson C. Brown. xv + 399 pp. Illus. $5.00. Wiley, New York. 1950.

MANY people do not realize the important part that forest industries play in the U. S. economy, nor do they recognize how many products are made directly from wood. In *Forest Products,* Professor Brown has discussed this vast field from both an economic and a general standpoint and has briefly taken up the fundamentals of the various processes used in the manufacture of a wide variety of items produced by the wood industries. He has not mentioned every use of wood, but he has covered all the major, as well as many of the minor, categories. These include not only the products made from wood but also chemically derived articles, as well as miscellaneous items that are products of the forest.

Brown has subdivided his topics into construction materials used in both light and heavy structures. (A discussion of lumber has been omitted, as the author has recently written a book on that subject.) Chemically derived products, which take in the materials produced from cellulose, the wood distillation processes,

the Naval stores industry, and the various extracts of wood; wooden containers such as cooperage and boxes; mechanically derived products, including excelsior, wood flour, and sawdust; wood fuel, which includes charcoal, fuel wood, and wood gas; and, finally, such miscellaneous products as Christmas trees, wild fruits, and nuts are discussed. Throughout the text constant reference is made to specialists in the various fields who have reviewed the content of the book.

The author has utilized his long experience as a teacher and recognized authority to present his information in a very interesting manner. Photographs, charts, and graphs are liberally used in the presentation of the subject. The text also includes a glossary, which will be an aid to the layman not familiar with the terms used in connection with the various articles described.

The book is a good text for a survey course or as a reference for someone who is primarily interested in the fundamentals of manufacturing the products concerned.

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The Nutritional Improvement of Life. Henry C. Sherman. 270 pp. $3.75. Columbia University Press, New York. 1950.

THIS book completes a group of three small volumes which was begun with *The Science of Nutrition* and continued in *Foods: Their Value and Management.* What is needed, and what this book seeks to aid, is not simply a further arousing of nutrition-consciousness but also the building of a sound understanding of what science has now shown to be practicable in the improvement of life processes and life histories through nutritionally guided use of food, and the significance of such improvements for the individual and for the human family. Nutrition is everyone's adventure.

Professor Sherman has drawn from his half century of teaching and research in the field of nutrition to weave a simple nontechnical presentation of the significance of the discoveries of nutritional research. He envisions what these contributions can mean for tomorrow rather than the investigations that brought them into being. An appendix contains a summary of the 1946 World Food Survey of the United Nations Food and Agriculture Organization. A second appendix gives records of actual meals served over a typical thirty-one-day period, which illustrate the application of present knowledge of nutrition to the diet. A selected bibliography, which includes reviews, abstracts as well as original references, concludes the book. Anyone who is interested in nutrition—and who is not?—will find this book of value.

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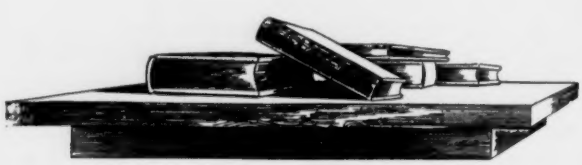
Quakers in Science and Industry. Arthur Raistrick. 361 pp. Illus. $6.00. Philosophical Library, New York. 1950.

HOW did it come about that the Quakers, a newly founded and a persecuted religious minority in the turbulent England of the 1650s, had risen to a commanding position in science and industry by the 1800s? What elements of Quaker doctrine and social organization were most responsible for this growth? Dr. Raistrick, a past president of the Friends Historical Association (London) and an authority on the geology of Northern England, undertakes to answer these questions by two major methods: an examination of the religious concepts of the Friends and the working exemplification of these concepts in the everyday lives of many tradesmen, financiers, industrialists, and scientists. Thus the book becomes, for the most part, a dry-as-dust biographical account of the day-to-day occurrences in the lives of his subjects. Indeed, unless one has a special mania for reading and remembering unessential details in the lives of Quakers during this period it hardly seems likely that he would turn to this book for enlightenment. There is, however, a valuable concluding chapter summarizing briefly the high lights of Quaker life and work.

What are the conclusions? Raistrick answers: "The genius of the young Society of Friends was its practical, working democracy, its complete respect for the individual, and its recognition of a real equality of person, irrespective of social or economic position, or sex." For this reviewer, Raistrick's conclusions seem plausible, but the enormous amount of detailed biographical labor expended in reaching them seems unnecessary. On the other hand, the collection in one book of these numerous out-of-the-way facts about the early Quakers could well serve the useful purpose of a reference book for historians and sociologists.

PERCY BLACK

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